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Full Length Research Paper

Effects of collaborative concept mapping teaching approach on secondary school students' achievement in biology in Nakuru North Sub-county, Kenya

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Abstract

This study sought to address the problem of ineffective instruction by teachers by investigating effects of Collaborative Concept Mapping Teaching Approach (CCMTA) on students' achievement in biology. The study used a Quasi-experimental research design, the Solomon Four Non-Equivalent Control Group Design. The study sample comprised of 202 Form two biology students and four biology teachers in four secondary schools. Purposive sampling technique was used to select the four schools from which a single stream per school was selected by simple random sampling. The four schools were randomly assigned into two experimental and two control groups E1 & E2, C1 & C2 respectively. A Biology Achievement Test (BAT) was used for data collection. Five educational research experts and three experienced biology teachers validated the research tool. Cronbach's Alpha Coefficient used to estimate its reliability and yielded a reliability coefficient of 0.86. Groups E1 and C1 were pre-tested prior to the intervention. The intervention period was three weeks after which all groups were post-tested. One-way ANOVA, t-test and ANCOVA were used to analyse the data generated with the aid of the Statistical Package for Social Sciences (SPSS). Kenya Certificate of Primary Education (KCPE) science scores for the sampled groups were used as covariates to adjust for possible pre-existing differences. Hypotheses were tested at 0.05 level of significance. The findings indicated that CCMTA had a significant effect on achievement in biology. The findings further indicate that there was no statistically significant gender difference in achievement after the intervention. It was concluded that CCMTA enhances the learning of school biology, minimizes the gender disparities often experienced in achievement of science subjects in secondary schools. The findings from this study provide a basis for improvement of in-service and pre-service biology teacher training programmes. It was, therefore, recommended that CCMTA be emphasized both in the pre-service and in-service teacher education programmes.

Keywords: Concept mapping, collaborative Learning, Achievement and Learning

INTRODUCTION

Performance of a country's students in science subjects has implications on the role that country will play in tomorrow's advanced technology sector, and for its general international competitiveness (OECD-PISA, 2003). Science education plays a critical role in the socio-economic development of a country. Biology is one of the science subjects that are offered at the secondary school

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cycle in Kenya. School biology equips learners with knowledge, skills and attitudes that are necessary for controlling and conserving the environment (KIE, 2002). Biology education is a pre-requisite for professions in health sciences, agriculture and environmental science and is also the precursor of biotechnology which is a tool for industrial and technological development. The knowledge of genetics which is a branch of biology has revolutionalised determination of paternity disputes and identity of serious crime culprits with precision and certainty through Deoxyribo-Nucleic Acid (DNA) sequencing and profiling (Institute of Biology, 2007). Biological knowledge has contributed towards conservation of the environment and endangered species (Muraya & Kimamo, 2011; UNESCO, 1986).

Although biology is a key science subject in secondary schools in Kenya, Kenya National Examinations Council reports (KNEC, 2012; 2011; 2010; 2009) indicate low achievement in biology at Kenya Certificate of Secondary Education (KCSE). In the years 2008 to 2011, the percentage mean scores were 32.4, 29.2, 27.1 and 30.32 respectively. Girls were reported to score lower than boys in biology. For the year 2011, the percentage means score for girls was 30.07 while that of boys was 34.53 (KNEC Report, 2012). This is an indication that learners face challenges in their learning of science/biological concepts and skills. The KNEC Report (2012), attributes low achievement to lack of skills in answering performance-based questions, inadequate understanding of biological concepts and inability to use technical terms in scientific communication. Muraya and Kimamo (2011) argue that students' negative attitude towards science subjects which they perceive as difficult; ineffective teaching approaches that are teacher rather than learner-centered; teachers' inadequate mastery of subject content and pedagogical skills; inadequate teaching and learning resources such as text books, laboratory equipments and apparatus contribute to poor performance.

Learner-centered teaching approaches promote imaginative, critical and creativity skills resulting in better achievement (Ministry of Education, 2001). However, the use of teacher-centered Traditional Teaching Methods (TTM) is pre-dominant in the teaching of school biology. The most widely used TTM is the Lecture Method (Taylor & Francis, 2011). UNESCO (1986) suggested adoption of teaching approaches that have the potential to motivate learners and involve them in active knowledge construction. Collaborative Learning (CL) is one such approach that engages learners in active learning where they work and learn together in small groups to accomplish shared goals (Panitz, 1996). This approach is characterized by group discussions which allow learners' expression and revision of their beliefs in the context of discourse (Sharan & Sharan, 1992; Bereiter & Scardamalia, 1993; Olson & Bruner, 1996). In CL, students explore their ideas, clarify them for themselves and to one another, expand and modify them, and finally make them their own. Collaborative Learning has positive effects on students' discussions in which they elaborate on the subject, challenge and amend one another's ideas, and thus remember these ideas more easily (Cohen, 1984). In small groups, students can share strengths, develop their weaker skills, interpersonal skills and also learn to deal with conflict. When guided by clear objectives, students engage in numerous activities that improve their understanding of a subject.

Concept mapping is the process of organizing concepts and relationships between them in a hierarchical manner from more inclusive concepts to more specific, less inclusive concepts (Novak & Gowin, 1984). Concept mapping is used to develop logical thinking and study skills by revealing connections and helping students see how individual ideas form a larger whole. The technique of concept mapping was developed by Novak (1970) as a means of representing the emerging scientific knowledge. It organizes knowledge in an understandable visual way and connects prior knowledge with new concepts by utilizing a visual structure for planning and thinking (Christodoulou, 2010). Christodoulou further argues that the human mind has the ability to organize knowledge in an orderly fashion. Knowledge is organized upon an existing framework or the learner's prior knowledge. When new ideas are presented to a learner, a framework of prior knowledge is constructed for the new ideas to attach to.

Weideman & Kritzinge (2003) suggest significant educational values of concept maps. They include increased efficiency of information retrieval, effective teaching via better course content communication and enhanced collaborative learning. The use of concept mapping enhances development of positive attitudes towards learning and improves text comprehension. It increases students' understanding and also brings order to complex tasks. Christodoulou (2010) suggests that using concept mapping enables learners to present prior conceptions and identify their weak points. A learner is able to use concept mapping to extract relationships between key concepts because knowledge is broken down into simple and more easily understandable parts. A concept map is a visual construction of a knowledge structure. It organizes and presents information easily using keywords. This promotes creative thinking hence self-directed learning. Concept mapping is an important pedagogical technique that provides an excellent means for a learner to externalize knowledge of a particular domain and to get meaningful understanding of new information.

Learning is a personal and unique experience that differs from individual to individual (Cicognani, 2000). It can be enhanced by concept mapping which is regarded as a powerful pedagogical process that fosters social creativity. Davidson (1998) indicated that when a learner is constructing a concept map, learning is enhanced and

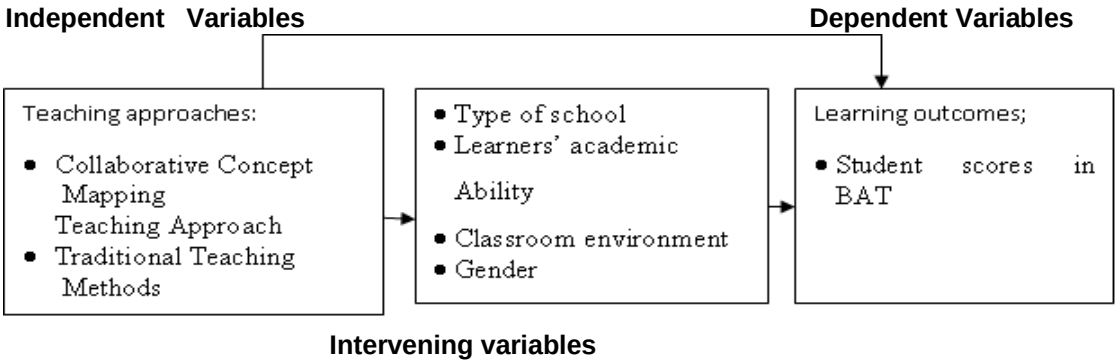

Figure 1: Interaction of variables that influence students' achievement in biology

becomes even more effective when constructed collaboratively. Collaborative concept mapping benefits from the interactions with others by allowing learners to blend their thoughts and experiences while trying to achieve understanding of a common concept.

Collaborative Concept Mapping

In concept mapping, collaboration is achieved in various phases. For example, in a brainstorming session, all participants collectively agree on the focus question. They contribute to the creation of a list of keywords that later will be used to give birth to the concept map (Cicognani, 2000). Collaboration is also achieved among the group through evaluation, questioning, discussion and debate with others. CCMTA is likely to be an effective summative assessment technique that engenders rich discussions amongst students who have already individually engaged with the concept mapping activity.

Collaborative Concept Mapping Teaching Approach (CCMTA) is a hybrid teaching/learning strategy involving an interaction between two or more individuals during concept mapping to create a shared understanding of a concept, discipline or area of practice that none had previously possessed or could have come to on their own (Johnson, Johnson & Smith, 1991). In the light of enlisted benefits of using CCMTA, this study investigated its effects on learners' achievement in biology in the second grade of the secondary school cycle.

Conceptual Framework

This study was conducted within an interpretive paradigm with a constructivist view of learning. In constructivist teaching and learning, learners are expected to actively construct meanings of concepts They are expected to construct meanings from input by processing it through existing cognitive structures and then retaining it in long-term memory (Okere, 1996). Figure 1 represents the conceptual framework that guided this study.

The social constructivist view of learning is the theoretical model that informed this study. It is based on the notion that knowledge is first constructed in a social context and is then taken up by individuals (Guba & Lincoln, 1994; Eggan & Kauchak, 2004). According to social constructivists, the process of sharing each person's point of view, called collaborative elaboration (Meter & Stevens, 2000), results in learners building understanding together that wouldn't be possible if they worked individually (Greeno, Collins & Resnick, 1996). The internal construction of knowledge is viewed as being driven primarily by social interaction (Wertsch, 1985). Collaborative Concept Mapping Teaching Approach was found to be consistent with social constructivism in its dimension of learning as learners engaged in active knowledge construction through social negotiation rather than competition.

The dependent variable in this study was learners' achievement in biology. In an ideal situation, the teaching influences learners' achievement. However, various intervening variables such as class room environment, type of school and learners' academic ability may affect the expected outcome. Gender was built into the study as a moderating variable that affects the association between independent and dependent variables (Baron & Kenny, 1986). To control for classroom environment, the study involved co-educational schools where boys and girls learn together in the same classroom. Type of school was controlled by involving one category of schools, the Sub-county secondary schools which enroll a majority of learners at the secondary school level in Kenya. Learners in each category of schools are of comparable academic ability because the Kenya Certificate of Primary (KCPE) examination scores is used for placement in secondary schools.

Objectives of the study

The broad objective of this study was to find out the effects of CCMTA on students' in biology in public secondary schools. To achieve this, the study compared achievement gains between students taught using CCMTA and those taught using Traditional Teaching Methods (TTM). The study also sought to find out if there was a gender difference in achievement when students

were taught using CCMTA. The specific objectives were to;

i. compare students' achievement in biology between those taught using CCMTA and those taught using the Traditional Teaching Methods (TTM);

ii. find out whether there is a gender difference in students' achievement in biology when exposed to CCMTA.

Hypotheses of the study

The following null hypotheses were tested:

Ho 1: There is no statistically significant difference in secondary school students' achievement in biology between students taught using the CCMTA and those taught using the TTM

Ho 2: There is no statistically significant gender difference in achievement in biology when learners are exposed to CCMTA.

Methodology

The study adopted the Solomon's Four Non-Equivalent Control Group design. This design was a quasi-experimental design that is considered sufficiently rigorous and appropriate for quasi-experimental studies (Fraenkel & Wallen, 2000). Quasi-experimental design was considered ideal for this study because participants were already constituted into permanent classes hence it was not ethical to randomly select them individually for experimental purposes (Gall, Borg & gall, 1996; Trochim, 2006). Besides, most school administrators were unlikely to allow breaking of classes for random assignment of learners into groups for experimental purposes. An important component of the quasi-experimental study is the use of pre-testing or the analysis of prior achievement to establish group equivalence. The Solomon Four non-equivalent Control Groups Design is represented in Figure 2.

Group I (E1)	O1	X	O2
Group II(C1)	O3	C	O4
Group III (E2)	-	X	O5
Group IV (C2)	-	C	O6

Key: O1 and O3 are pre-tests; O2, O4, O5 and O6 are post-tests: X is the treatment: C is control condition.

Group E1 received the pre-test, the treatment X and the post-test.

Group C1 received the pre-test, control condition and a post-test.

Group E2 received the treatment X and a post-test.

Group C2 received the post-test only.

Groups E1 and E2 were taught using CCMTA while groups C1 and C2 were taught using conventional methods.

Quasi-experimental procedure controls for all major threats to internal validity except those associated with interactions of selection and history, selection and maturation, and selection and instrumentation (Cook & Campbell, 1979). To control for interaction between selection and maturation, the schools were assigned randomly to the control and treatment groups. In the sampled schools, no major event occurred that would have led to interaction between selection and history. To control for interaction between selection and instrumentation, the conditions under which treatment was administered were kept as similar as possible in all the sampled schools (Gall et al, 1996).

The schools were used as sampling units for the subjects of the study since learners operate as intact groups (Gall *et al,* 1996). Each of the schools included in the study was, therefore, treated as a group. The study used Sub County secondary schools because a majority of students attend these schools. A list of Nakuru North Sub County secondary schools in Nakuru County was used as a sampling frame. Purposive sampling technique was used to select four co-educational schools that offer biology. A total of 4 biology teachers and 202 students in the second grade in the secondary school participated in this study. The average age of grade two students in Kenya is 15 years. The total number of students in each of the Groups E1, C1, E2 and C2 were 47, 54, 55 and 46 respectively. In schools that had more than one grade two stream, simple random sampling was used to pick one stream. to provide the four groups for the study. The four schools were randomly assigned to treatment and control groups to control for interaction between selection and maturation (Best & Kahn, 2003). Biology teachers in the experimental schools exposes all the grade two students to CCMTA for ethical reasons, but data from one stream that was randomly sampled was used analyzed in this study.

A Biology Achievement Test adapted from Kenya National Examinations Council (KNEC) past examination papers was used to measure students' achievement in biology. It consisted of forty structured short answer questions drawn from the topic Gaseous exchange in plants and animals. BAT had a maximum of 100 marks. Test items were categorized into three cognitive ability levels of knowledge, comprehension and application. The reliability coefficient of BAT was estimated using the Cronbach's alpha (α) coefficient. It yielded a reliability coefficient of 0.86. This was above the recommended threshold of 0.7 hence the instrument was considered ideal for the study.

Development and Use of Instructional Materials

A CCMTA teacher's manual was developed based on the biology syllabus in use in secondary schools in Kenya). Teachers of the experimental groups were trained on skills of collaborative concept mapping for one week.

Table 1: Pre-test BAT means scores' independent samples t-test results

Variable	Group	Mean	SD	df	t-value	p-value
Teaching approach	E_1	17.48	12.36	98	1.810	0.073
	C_1	13.85	7.39			
Gender	Male	17.14	12.19	98	1.426	0.157
	Female	13.25	7.98			

Group E1, N= 46; Group C1, N= 54 Male= 44; Female= 56

Table 2: Students' post-test BAT mean scores

Group	N	Mean	SD
E1	47	27.68	15.13
C1	54	21.59	10.22
E2	55	30.22	4.77
C2	46	15.35	8.53

Table 3: Post-test BAT ANOVA results

Scale	Sum of squares	df	mean squares	F-ratio	p-value
Between groups	6519.097	3	2173.032	20.928	0.000*
Within groups	20559.066	198	103.834		
Total	**27078.163**	**201**			

They practiced using CCMTA on a different topic other than Gaseous exchange in plants and animals for one week to enable them master the skills. The pre-test was administered to groups E1 and CI before the commencement of the intervention. Control groups were taught using TTM. After the three weeks intervention period, the post-test was administered to all the groups. Data generated was analysed using one-way ANOVA and t-test. Analysis of variance (ANOVA) was used to test whether the four groups differed significantly on their achievement. The t-test was used to test whether there was a gender difference in achievement.

RESULTS

The Results of the t- test of the pre- test BAT scores for groups E1 and C1 are presented in Table 1. The table also presents the t- test results of the gender comparison in achievement before the interventions.

The t-test results of the pre-test on BAT for E1 and C1 show that there no statistically significant difference at the 0.05 level since t (98) =1.810, p>0.05. The t-test of results of the BAT pre-test presented in Table 1 further indicate a non-significant gender difference in achievement. This means that achievement in biology of male students was similar to that of female students before commencement of treatment.

Effects of CCMTA on students' achievement in biology

To determine the relative effects of CCMTA on student's achievement in biology, an analysis of students' BAT was carried out. The students' BAT means scores from the four groups were compared and the result is presented in Table 2.

Experimental groups E1 and E2 had higher mean scores than control groups. The means of groups E1, E2, C1and C2 were 27.68, 30.22, 21.59 and 15.35 respectively. One- way ANOVA was carried out to find out whether these means were statistically significant and the results are presented in Table 3.

Result reveals that the difference between the means of the four groups was statistically significant since F (3, 198) =20.928, p< 0.05. Post-hoc tests of multiple comparisons using Bonferroni test was done to point out the source of the observed significant differences among the group means. The results are presented in Table 4.

Bonferroni test is considered ideal for making multiple comparisons since it is flexible for use with any set of statistical tests (Howel, 2002). Use of Bonferroni procedure with $\alpha = 0.05$ guarantees that the probability of any false rejection among all the comparisons made is no greater than 0.05. This is a much stronger protection than controlling the probability of a false rejection at 0.05 for

Table 4: Bonferroni Post-Hoc pair wise Multiple Comparisons test Results of the Post-test BAT Mean Scores for the Four groups

	Group (I)	Group (J)	Mean difference (I-J)	p- value
Bonferroni	E1	C1	6.09	0.032*
	E1	E2	-2.54	0.666
	E1	C2	12.33	0.000*
	E2	C2	14.87	0.000*
	C1	E2	-8.63	0.000*
	C1	C2	6.24	0.067

*The mean difference is significant at p< 0.05

Table 5: T-test results 0f Post-test BAT Mean Scores for Boys and Girls Exposed to CCMTA

Gender	N	Mean	SD	df	t-value	p-value
Male	40	30.15	13.10	100	0.821	0.414
Female	62	28.34	9.19			

each separate comparison (Orora *et al* 2013). Table 4 presents results of Bonferroni Post-Hoc test.

It is observed that the difference between the mean scores of experimental and control groups is statistically significant in favor of experimental groups. Results reveal that there were significant differences between group pairs E1 & C1 (p= 0.032), E1 & C2 (p= 0.000), E2 &C2 (p= 0.000) and E2 & C1 (p= 0.000). However, there was no statistically significant difference between the mean scores of E1 & E2 (p= 0.666) and C1 & C2 (p= 0.067) at the 0.05 level. This difference in achievement, therefore, can be attributed to the intervention where CCMTA was used.

These results indicate that;

i. There was no significant interaction between BAT pre-test and the treatment conditions. Otherwise pre-tested groups would have obtained significantly different results from those who did not take the pre-test.

ii. Application of CCMTA resulted in higher student achievement than the TTM that was used to teach control groups since groups E1 and E2 obtained scores that were significantly higher than those of other groups. Hypothesis Ho1 was therefore rejected.

Effects of CCMTA Achievement of Boys and Girls

Results of pre-test indicated no significant gender difference in achievement before the intervention (see Table 1). To find out whether there was a gender difference in achievement after students were exposed to CCMTA, the BAT post-test mean scores of boys and girls in experimental groups were analyzed and compared to determine whether there was a significant difference between them. The BAT post-test mean scores were subjected to a t-test. The results are presented in Table 5.

The results in Table 5 reveal that male students had a slightly higher mean score (M=30.15, SD= 13.10) than female students (M= 28.34, SD = 9.19). However, the mean scores of male and female students were not statistically different at 0.05 level; t (100) =0.821, p>0.05. The results, therefore, indicate that gender had no influence on learners' achievement since both boys and girls benefited equally when CCMTA was used. On the basis of this result, the second hypothesis of the study was accepted.

DISCUSSION

The results of this study reveal that students who were taught using CCMTA achieved significantly higher scores in BAT than those taught using the conventional approaches. The findings are in line with those of Keraro *et al* (2007). Their findings revealed that secondary school students exposed to cooperative concept mapping teaching approach performed better in biology than their counterparts taught using the traditional teaching methods. The results are also consistent with those of Wambugu (2011) which showed that experiential cooperative concept mapping instructional approach enhances secondary school students' achievement in physics. An earlier study conducted by Muraya and Kimamo (2011) to determine the Effect of Cooperative Learning Approach on Mean Achievement Scores in Biology found significant differences. Students who were taught using Cooperative Learning Approach attained significantly higher mean achievement scores compared to those taught using regular teaching approach. Namasaka (2009) studied the Effects of Concept and Vee Mapping Strategy (CVMS) on Students' Motivation and Achievement in Biology and found out that students taught using the CVMS exhibited improved achievement in secondary school biology. His results also indicated reduced gender disparity in achievement.

In his study on Which Strategy Best Suits Biology Teaching, Ajaja (2013) observed that students taught

using Cooperative Learning significantly outscored those taught using lecture method on achievement tests. Male and female students did not significantly differ in achievement tests; Students in learning cycle and cooperative learning groups did not significantly differ on achievement tests. Non significant interaction effect between sex and method of instruction on achievements was reported. Kinchin (2000a) observed a significant impact of Concept Mapping on Achievement when used for instructing secondary school biology students. This study reveals that CCMTA offers students opportunity to construct knowledge and yields the best results if students work in small groups made up of members of mixed abilities. The CCMTA was found to be more effective in enhancing learners' achievement than the conventional teaching approaches.

Effect of CCMTA on achievement by gender

The results of this study have indicated that there is no statistically significant difference between the achievement of boys and girls who are exposed to CCMTA. The results also show that boys and girls who were taught using CCMTA achieved significantly higher scores than those taught using the regular teaching methods. A classroom environment that seems to favor boys tends to discourage girls' participation in learning. Teachers who give more attention to boys at the expense of girls during instruction discourages girls and negatively affect their self confidence (Kelly, 1998). In their study on Using Advance Organizers to Enhance Students' Motivation in Learning Biology, Keraro and Shihusa (2009) found significantly higher level of motivation among boys than their female counterparts. However, CCMTA enabled both boys and girls to participate equally hence acquired comparable motivation.

Girls have been found to exhibit low levels of self esteem which makes them underestimate their abilities. This attitude leads to low motivation levels and poor performance especially in science subjects as they are deemed a male domain (Stake 2006). The use of CCMTA gives contrary findings. When boys and girls are subjected to the same learning environment, they reflect significantly comparable achievement in biology. This is a strong indicator of gender parity that ensures access to prestigious careers. Given the same educational opportunities and a gender positive teaching approach, girls are likely to perform at par with boys. CCMTA seems to provide opportunities for students to interact, share knowledge and apply acquired knowledge to real life situations. Activities related to CCMTA generate intrinsic motivation and self-directed learning as students take full responsibility of their own learning and that of their peers during knowledge construction.

CONCLUSION

Based on the results of ANOVA and ANCOVA, significant differences were found between the means of groups taught using Collaborative Concept Mapping Teaching Approach (CCMTA) and those taught using conventional teaching methods. Gender had no effect where CCMTA was applied. Thus, CCMTA enhanced students' achievement in biology compared to conventional teaching methods. CCMTA also mitigated against gender differentials in achievement.

Implications of the study

The findings of this study have indicated that the use of CCMTA enhances achievement in biology. Gender was found to have no effect when CCMTA was applied. The superiority of CCMTA over the regular teaching method can be attributed to the fact that it is an integration of two learning approaches; collaborative learning and concept mapping. It should therefore be incorporated in teaching secondary school biology to supplement the existing approaches. All the components of CCMTA should be incorporated in teacher education to enhance learning in secondary schools. Educators and curriculum developers should incorporate the concepts of CCMTA when developing secondary school curriculum and preparing teaching materials such as text books and teachers guides to support biology syllabus.

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