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Original Paper

Effects of Concept Mapping Teaching Approach on Secondary School Students' Achievement in Biology in Kitui County, Kenya

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Abstract

This study investigated the impact of the Concept Mapping Teaching Approach (CMTA) on Biology achievement among year four students in selected secondary schools in Kitui County, Kenya. The Solomon Four Non-Equivalent Control Group design was used. The target population included all secondary school Biology students, while the accessible population comprised Form Four students from co-educational secondary schools in the county. A purposive sample of four secondary co-educational Sub County schools was selected. Two schools were randomly assigned as experimental groups and the remaining two schools served as control groups. The study sample comprised 173 Form four Biology students. Biology Achievement Test (BAT) was used to collect data. The BAT was validated by five experts. The reliability of BAT was estimated using Cronbach's alpha coefficient formula. This yielded a reliability coefficient of 0.78. One-way ANOVA, ANCOVA and t-tests were used to analyze data at 0.05 level of significance. Results indicated that students exposed to CMTA showed significant improvements in their biology performance. Additionally, the study findings indicate that CTMA bridged the gender disparity in achievement.

Keywords

Concept Mapping Teaching Approach (CMTA), biology achievement, secondary school student, learning biology

1. Introduction

Science is a vital vehicle for industrial and technological development. Science, Technology & Innovations (ST&I) is key in industrialization, economic growth and achievement of Sustainable Development Goals (SDGs) (Republic of Kenya, 2021). Kenya is among the African nations that aim to accomplish the seventeen SDGs by 2030, as per the United Nations summit that took place in New York in 2015. In addition, Kenya aspires to transform the economy as per its overall objective, "Transform Kenya into a newly Industrializing, middle income country that can provide high quality of life to all its citizens by the year 2030 in a clean and secure environment" (Republic of Kenya, 2021). Biology, as a cornerstone of life sciences, plays a vital role in addressing some of humanity's most pressing challenges, aligned with SDGs like eradicating extreme poverty, mitigating hunger through food security and enhanced nutrition and ensuring healthy lives for all. Here is how biology contributes to these goals.

Biological knowledge forms the basis of agriculture, which is a major contributor to Kenya's economic growth. Biological knowledge has been employed by researchers to produce fast maturing crop varieties and animal breeds that are both resistant to diseases and high yielding facilitating the feeding of ever increasing world's population.

The student with an interest to pursue careers in Science, Technology, Engineering and Mathematics (STEM), need to achieve a quality grade in Biology at Kenya Certificate of Secondary Education (KCSE) examination. KCSE results between 2017 to 2022 indicate poor achievement in Biology (KNEC, 2022). Biology results at KCSE for the sampled years (2017-2022) demonstrate poor performance as they range between 23.26% and 29.50% (KNEC, 2022). Low achievement would mean that learners may not have acquired basic understanding of biological concepts and skills. This could signal that mastery of biological concepts presents major challenges to secondary school students. This low achievement in Biology has raised serious concerns among education officers, parents, schools' Board of Managements (BOM) and school sponsors (KNEC, 2017). This prevailing poor performance has been partly blamed on the use of unproductive teaching approaches by Biology teachers, with majority settling on the application of Conventional Teaching Methods (CTM). Available data indicates that implementing various teaching approaches that engage learners can improve both academic performance and the desire to learn the subject (Ajaja, 2013; Smith, 2010; Kinchin, 2011; Ongowo, Keraro & Okere, 2011; O'Neill & McMahon, 2005; Stanisavljević & Stanisavljević, 2014). To realize excellent performance of this core science subject, it is imperative that those biology teachers use leaner-centered active learning strategies. This is because learner-centered strategies have been found to enhance learning (Ministry of Education, 2012). Additionally, it has been established that the commonly applied method is the chalk and talk method (Abogonye, 2015).

This study also took into account the gender disparities in Biology achievement. According to the Kenya National Examination Council (KNEC) (2021), girls achieved lower grades in KCSE Biology examinations compared to boys. Gender stereotyping is the cause of gender inequality (UNESCO,

2021). This study investigated the impact of using concept mapping in bridging the gender disparity in achievement in Biology.

Concept maps are the graphical tools used by learners to visually represent concepts and their interrelationships. They consist of at least two concepts connected by a linking word forming a proposition (Novak, 1984). This approach integrates multiple diagrams to justify, yet explain the relationship between two concepts and another by showing clearly the link between the superordinate concept and the subordinate one, thus helping to improve the understanding of the concepts. The procedural concept is made seamless by introducing these through pyramids that help arrange concepts in hierarchical order. Ongowo, Keraro, and Okere, (2011) found that the use of Concept Mapping in the teaching of Biology enhanced learners' attitude towards the subject and thus equally improving achievement. Their finding suggests that the use of a more interactive approach, students' engagement can be enhanced and thus improve their achievement. A study by Enebechi and Nzewi, (2021), has shown that the use of CMTA is able to enhance students' achievement. This study also showed that, the use of CMTA is capable of bridging the gender disparity in achievement.

1.1 The Purpose of the Study

The purpose of this study was to analyze how the Concept Mapping Teaching Approach (CMTA) impacted on the academic achievement of high school Biology students in Kitui County, Kenya.

1.2 Objectives of the Study

The specific objectives that guided this study were to:

i. Examine if there exists a statistically significant difference in students' performance in Biology between the students taught using CMTA compared to those taught using CTM.
ii. Investigate if there is a gender difference in achievement in Biology when Concept Mapping Teaching Approach (CMTA) is used.

1.3 Hypotheses of the Study

Hypotheses tested were:

$H_0$1: There is no statistically significant difference in achievement in Biology between students who were taught using CMTA and those who taught using CTM

$H_0$2: There is no statistically significant gender difference in achievement in Biology when instructed using CMTA.

1.4 Conceptual Framework

Constructivist learning theory served as the foundation for the study's conceptual framework. In this study the Concept Mapping Teaching Approach is considered an effective intervention during the teaching-learning process on the topic of support and movement in animals as shown in Figure 1.

Figure 1 provides a graphical representation of the study's conceptual framework. The left side of the figure displays the independent variables, the central section is dedicated to the intervening variables and the right side is designated for the dependent variables. The independent variables included

Concept Mapping Teaching Approach (CMTA) and Conventional Teaching Methods (CTM). Achievement in Biology is the dependent variables in this study.

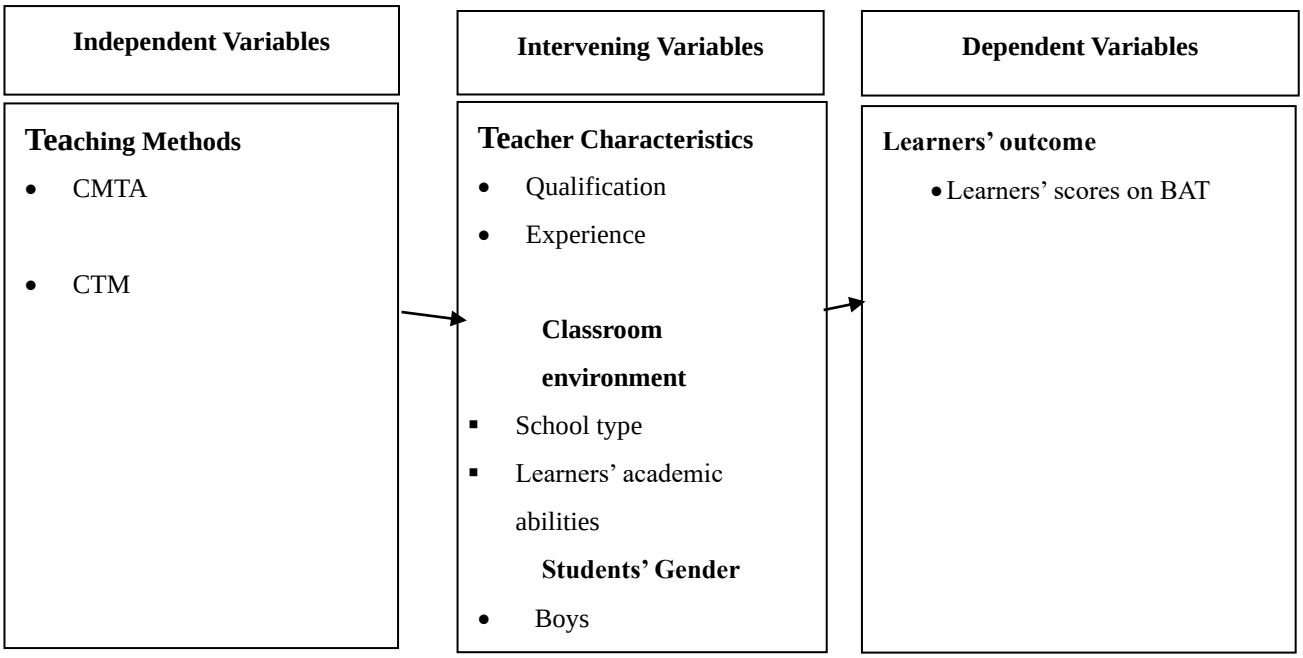

Figure 1. Conceptual Framework for Determining the Effect of Employing CMTA on Secondary Schools Students' Achievement in Biology

However, there were two more variables: the classroom environment and the characteristics of the teacher. These were intervening variables which needed to be checked. For this study, teacher characteristics included teacher qualifications and teachers' work experience. To control on these, all the teachers involved had at least a Diploma in Education qualification and a minimum of at least three years teaching experience. For the learners' academic ability, sub–county schools were used because they enroll students with comparable academic abilities based on their Kenya Certificate of Primary Education Examination (KCPE) results. In this study, gender served as a confounding variable that could affect how an independent and dependent variable were related to one another, Githae, Keraro and Wachanga (2015). To control for this variable, the researcher used co-educational institutions where students of both gender share a classroom. Gender as a variable also formed part of the study.

2. Research Methodology

The research design used for this study was the Solomon IV Non-Equivalent Control Group approach. This design is adequate for studies that are not pure experiments. Secondary school classes were treated as one large unit; this disallowed teacher to divide them into respective parts for use with research purposes (Gall, Gall, & Borg, 2015).

The Solomon Four Non-equivalent Control Group Design:

GROUP	PRE-TEST	TREATMENT	POST-TEST
Group 1	O_1	X	O_2
Group II	O_3	C	O_4
Group III	—	X	O_5
Group IV	—	C	O_6

Source: Gall et al. 2015.

Figure 2. Solomon Four, Non-equivalent Control Group Design

Where: O_1 and O_3 were pre-tests: O_2, O_4, O_5 and O_6 were post-tests.

Dotted lines signified that students existed as intact groups hence no randomization of students were done.

Dash (-) implied no pre-test was carried out in groups III and IV.

X was the treatment which represented learners that were taught using Concept Mapping Teaching Approach (CMTA).

C was the control condition which implied teaching Support and Movement in Animals using Lecture method.

Group I took the pretest as a member of the experimental group, received the therapy (X) and then completed a post-test.

Group II served as the control group, which took a pre-test, experienced the control condition (C) and subsequently took a post-test.

Group III was another experimental group that received therapy X and a post-test, but no pre-test.

Group IV functioned as a second control group and was administered only the post-test.

The Lecture Method was employed to instruct Groups II and IV.

2.1 Target Population and Accessible Population

The study's target group was all Kitui County secondary school Biology students with an average age of 18 years. Form four biology students from sub-county co-educational schools were the accessible population.

2.2 Sample Size and Sampling Procedures

The study sample had 173 students. Purposive sampling was used to select the schools that participated in the study. Purposive sampling is referred to as the process of selecting cases that manifest the phenomenon of interest (Mugenda & Mugenda, 2013). This is because not all sub-county schools had all the requirements for the research. The requisites for the schools were a science laboratory that can adequately cater for science experiments, almost equal numbers of boys and girls in a class and tutors of Biology subjects with teaching experience of at least three years and a minimum qualification of a Diploma in secondary education.

2.3 Instrumentation

Data was collected using the Biology Achievement Test (BAT). The BAT had 25 items drawn from the topic support and movement in animals. The test items were short answer items. The scores for the test items ranged from 1 to 4 marks. These scores totaled 60 marks, which were then converted to a percentage out of 100%. All items adapted an open-ended format. BAT was validated by five research experts in Science Education. A pilot test was carried out at two Kitui County sub county schools, separate from those included in the main study. The pilot study results were used to estimate the reliability of the BAT. Cronbach's coefficient alpha formula was used to estimate the reliability because the test items were not dichotomously scored. The BAT achieved a reliability coefficient of 0.78, which is above the threshold of 0.70 (Mugenda & Mugenda, 2003).

2.4 Data Collection Procedures

BAT was administered as a pre-test to two groups; one experimental group and one control group before the treatment. Thereafter, experimental groups were taught using CMTA while the control groups were taught using the CTM. All groups were taught by their regular teachers. After four weeks of the intervention, all four group categories received a post-test BAT.

2.5 Data Analysis Procedure

Pre-Test scores were analysed using the t-test to test the homogeneity of the groups before treatment. To test hypothesis one, the Post-test scores for the four groups were analysed using A one-way ANOVA. A t-test was employed to test hypotheses two. All tests were checked for significance at a 0.05 alpha level of significance.

3. Results

3.1 Pre-test Results

The pre-test was very significant in making sure that the control and experimental groups were equivalent. An independent sample t-test was done to determine if there was a significant difference in the averages of the scores for the two groups. The results of the t-test are shown in Table 1. Pre-test BAT scores for boys and girls were compared to find out if the groups were comparable.

Table 1. Pre-Test Mean Scores on BAT and Independent Samples t-Test Results

Group 1, N=36;	Group 2, N=44;	Boys =38	Girls=42			
Variable	*Group*	Mean	SD	df	t-value	p-value
Method of instruction	Group 1	16.47	5.02	78	0.2936	0.7698
	Group II	16.84	5.09			
Gender	Boys	17.10	5.93		0.6489	0.5183
	Girls	16.29	5.09			

The results in Table 1 indicate that at a 0.05 significance level, the difference between the mean scores of Groups I and II was not statistically significant, with t(78)=0.2936, P=0.7698, and P>0.05. Therefore, the two groups were comparable and appropriate for use in the study.

3.2 Post -Test Results

3.2.1 The Impact of CMTA on Students' Biology Performance

H_o1 aimed at determining whether there was a significant difference in achievement in Biology between students who were taught using CMTA and those who taught using CTM. The impact of CMTA on students' Biology performance was assessed by analyzing the post-test BAT mean scores. Table 2 shows the mean scores for the four groups.

Table 2. Students' Post-Test BAT Mean Scores for Four Groups

Group	N	Mean	SD
Group I	36	30.055	8.042
Group II	44	22.022	7.283
Group III	47	30.127	8.940
Group IV	46	23.279	7.159

According to the results in Table 2, the experimental groups I (M=30.055, SD=8.042) and III (M=30.127, SD=8.940) had higher mean scores compared to the control groups II (M=22.022, SD=7.283) and IV (M=23.279, SD=7.159). This demonstrates that in the BAT post-test, experimental groups outperformed control groups. An ANOVA was conducted to assess if there were statistically significant differences in the group mean scores. The results are presented in Table 3.

Table 3. Results of Post-Test BAT ANOVA

Scale	Sum of Squares	Df	mean squares	F-Ratio	p-value
Between treatment	2329.0552	3	776.3517	F=12.4613	0.000*
Within treatment	10528.8176	169	62.3007		
Total	12857.8728	172			

The results in Table 3 indicate that with F (3, 169)=12.4613 and p=0.000*, there was a statistically significant difference between groups at the 0.05 level.

Due to this, it was necessary to identify where the differences between the group means existed using the Post Hoc pairwise multiple comparisons test. Since it may be applied to any combination of statistical tests, the Bonferroni test was thought to be the most suitable option when conducting multiple comparisons (Howel, 2002). Table 4 presents the results.

Table 4. Pairwise Post-Hoc Multiple Comparisons Test Results for Post-Test BAT Mean Scores Across the Four Groups

Group (I)	Group (J)	Mean Difference(I-J)	p-value
Group I	Group II	8.032	0.000*
Group I	Group III	0.0721	1
Group I	Group IV	6.4251	0.0019
Group II	Group III	8.1049	0.000*
Group II	Group IV	1.6077	0.769
Group III	Group IV	6.4972	0.000*

Table 4 results show that group pairs I and II (p=0.000*), I and IV (p=0.0019), II & III (p=0.000*) and III & IV (p=0.000*) differed significantly from one another. Nonetheless, there was no statistically significant difference between group II & IV (p=0.769) and group I & III (p=1). Additionally, it was noted that there was a statistically significant difference in favor of the experimental groups between the mean scores of the control and experimental groups. It can be, therefore, argued that this variation was occasioned by the use of CMTA in the intervention.

3.3 Achievement Levels of Male and Female Students Exposed to CMTA

$H_0$2 of the study stated that there is no significant gender difference in achievement in Biology between students exposed to CMTA. This hypothesis was tested by analyzing the mean scores obtained by boys and girls in the post-test BAT after they had been subjected to CMTA. The t-test was used to test whether there was a statistically significant difference between the mean scores of the male and female students. The results are presented in Table 5.

Table 5. t-Test Results of Post-Test BAT Mean Scores for Male and Female Students Exposed to CMTA

Gender	Mean	SD	Df	t-value	p-value
Boys	30.36	11.27	76	-0.302	0.3816
Girls	29.79	7.19			

Results in Table 5 show that the mean score of the male students was slightly higher (M=30.36, SD=11.27) than that of female students (M=29.79, SD=7.19). However, there was no statistically significant difference between the two means at the 0.05 level: t(76)=-0.302, p>0.05. This would suggest that both the male and female students equally benefited from the implementation of CMTA. Therefore, hypothesis two of the study is accepted. The results of the study establish that there is no statistically significant gender variance in achievement when students are exposed to CMTA.

4. Discussion

The results of this study indicate that the experimental groups exposed to the Concept Mapping Teaching strategy had significantly better achievement compared to the control groups, the null hypothesis ($H_0$1) was rejected. The study's results depicted that the students taught using CMTA registered better BAT scores compared to students instructed by CTM. The findings also support a study reported by Keraro, Wachanga and Orora (2007). Their study concludes that form two secondary school students who were instructed using cooperative concept mapping performed better than students instructed conventional methods. The results also agrees with Wambugu (2011), who revealed that experiential cooperative concept mapping did enhance the achievement of a secondary school students in physics. The current findings also concur with Githae, Keraro and Wachanga (2015) which revealed that collaborative concept mapping teaching approach in a secondary school enhances achievement in Biology.

Objective two sought to investigate if the application of Concept Mapping Teaching Approach (CMTA) among boys and girls elicits a difference in Biology attainment. The results of the study have established that there is no statistically significant gender difference in achievement when students are exposed to CMTA. The same results also indicate that students who were taught using CMTA scored far above those taught using CTM. The study's findings are consistent with the works by Ayimbila and Akantagriwon (2021), which examined the effects of incorporating concept mapping into instructional strategies and using discussion webs for biology students. Their research explored how these methods influenced students' academic performance while learning and teaching genetic concepts. The findings of this research align with Okoronka's (2020) study, which suggested that the concept mapping strategy has the potential to enhance learner performance by improving conceptual understanding and comprehension, without any gender bias. Concept maps, according to Izci and Akkoc (2023), are found to be very effective in enhancing academic achievement and therefore should be used in the education process. Conclusions of this study also buttress Wanjala, whose study in (2023) investigated the effects of advanced organizer concept mapping teaching technique on academic achievement and physics learning and motivation of secondary school students in Rongai Sub-County in Kenya. According to Wanjala, teaching secondary school students by using an organizer concept mapping raises their level of achievement. The findings of this study corroborate with those of Ogonnaya, Okechukwu and Ugama (2016) which found out that the concept mapping approach is superior to the conventional approach in fostering both achievement and retention in basic science. Results obtained from this study concur with those of Woldeamanuel, Abate and Berhane (2020) which found out that students taught using concept mapping had higher scores in achievement test than those taught using conventional teaching methods. The findings of this study further agrees with those of Tete and Cornelia (2020), in their study, they observed that concept mapping enhanced students' achievement in social studies.

5. Conclusions

The findings of this study indicate that:

i. The use of CMTA for instruction in Biology enhances students' learning.

ii. The use of CMTA eradicates gender disparities in students' achievement.

6. Implications of the Findings

The results suggest that CMTA boosts Biology performance, and hence it is a more superior instructional strategy than CTM. This approach would improve KCSE performance among girls, addressing their historically lower scores compared to boys. This makes CMTA a more effective teaching method that reduces rote memorization and enhances cognitive learning.

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