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Influence of Science Technology Engineering and Mathematics (STEM) Education Programme on Students' Performance in Chemistry in Extra-County Secondary Schools In North-Rift Region, Kenya

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The study examined the influence of Science, Technology, Engineering, Mathematics (STEM) education programme on students' performance in chemistry in extra County Secondary Schools in North-Rift Region, Kenya. The study sought to establish the extent of students' performance in Chemistry in extra county secondary schools as an effect of Science Technology Engineering and Mathematics (STEM) education programme. The study was anchored on Social Learning Theory. Causal comparative *ex post facto* research design guided the study. The target population was 3550 form four students and 175 teachers of chemistry. Simple random sampling was used to select six Counties in North-Rift Region. Stratified random sampling was used to separate schools into STEM and non-STEM schools and simple random sampling technique was then used to sample out students and teachers. The sample size consisted of 1092 respondents. Data were collected using a document analysis schedule and a chemistry achievement test. Reliability of the evaluation instruments was examined using test-retest method. Data were analysed using descriptive statistics and hypotheses were tested using t-test for independent groups. The study findings revealed that chemistry performance among students was good while the hypotheses results established that: students' performance in chemistry in STEM schools (Mean 21.68, SD 6.17) was higher than in non-STEM schools (Mean 19.06, SD 7.15) and a significant difference existed between students' performance based on gender whereby boys performed better than girls. Chemistry performance in schools was greatly associated with STEM Education programme under implementation, which was more effective in STEM schools than in non-STEM schools. The number of chemistry projects presented by students was higher in STEM (173) than in non-STEM schools (144). The study recommends that students should initiate STEM activities during club days. This will enable them to design and improve the quantity and quality of chemistry projects hence enhancing creativity and innovation.

Keywords: STEM Education, Chemistry Performance, Social Learning Theory, North Rift Kenya

Introduction

Background to the Problem

Science, Technology, Engineering and Mathematics (STEM) was introduced in selected Extra County Secondary Schools in Kenya in the years 2016 and 2017. Implementation of STEM education programme was done in 102 extra county secondary schools whereby promotion of inviting school climate in terms of the 5ps (people, process, policies, programs and place) was emphasised; promotion of creativity and innovation among students and creation of Maker Space or innovation room in each of the selected STEM Model schools.

The implementation process in Kenya is coordinated by the Centre for Mathematics, Science, and Technology Education in Africa (CEMASTEA). Selection of STEM schools and implementation of STEM education programme in Kenya was guided by several policies in education namely: The Kenya Constitution of 2010; Science, Technology and Innovation Policy and Strategy (2008); Basic Education Act of 2013 and Sessional Paper No. 2 of 2016 which promoted education reforms and training in Kenya. The Institute for Capacity Development of Teachers in Africa (ICADETA) Strategic Plan also referred to as the CEMASTEA Strategic Plan of 2014-2019 strived to strengthen teachers' skills in STEM.

CEMASTEA was supposed to initiate a programme that would promote STEM activities for example student competitions and exhibitions. CEMASTEA was also to sensitise students, teachers and all other school stakeholders on

STEM functions towards achieving sustainable development (CEMASTEA, 2014). It is therefore through this plan that STEM education programme was initiated and rolled out in the selected schools. STEM education programme was developed to guide implementation of STEM activities in schools. Teachers of mathematics and sciences together with principals were trained on the expectations of STEM schools. According to the STEM programme, mathematics, physics, chemistry and biology are supposed to be taught as one since they are interrelated; learner centred teaching methodologies are emphasised; creativity and innovation among learners should be championed; students' attitude towards mathematics and sciences will improve and effective utility of teaching/learning resources will also be realised.

Student discipline will improve and learner enrollment will also rise. All these will in turn affect students' performance in mathematics and sciences. Ministry of Education through CEMASTEA promotes STEM implementation through STEM education programmes in selected Kenyan secondary schools. This is the sixth year since STEM education programme was rolled out in schools in Kenya. Its effects have already been felt in the selected institutions and other schools which have benefitted from STEM schools.

During the World Economic Forum (2017) held in Geneva, young people were encouraged to study science, technology, engineering and mathematics subjects for a more employable workforce to be created in different Nations. The subjects could enable students to acquire employment than those who have pursued other courses. Evaluation of STEM education was done by Stith (2017) in Missouri who established that STEM had impacted the learning outcomes of students and provided a continuous improvement in curriculum implementation. Sanchez (2019) evaluated a Pilot Robotics Programme and established that students' exposure to robotics influenced students' attitudes towards STEM and related careers.

STEM has also been adopted by various countries in Africa seeking to integrate STEM education into secondary education. For instance, White and David (2014) established that STEM Education has allowed students to expand their capabilities of problem-solving and promoted critical thinking skills to students in South Africa. Manoah, Indoshi and Othuon (2011) conducted a study in Kenya to examine students' attitude and performance in mathematics in public secondary schools and established that students' performance was influenced by attitude whereby students with positive attitude performed significantly better in examinations than those with negative attitude.

Statement of the Problem

Performance of students in National examinations in STEM subjects (Mathematics, Physics, Chemistry and Biology) in most secondary schools in Kenya has been low, according to Kenya National Examinations Council (KNEC) yearly reports. The national mean scores for chemistry since the inception of STEM programme in secondary schools were: 28.01 (2021), 30.19 (2020), 20.71 (2019), 24.05% (2018), 26.90% (2017) and 26.10% in 2016. North-Rift Region forms part of the Rift Valley Region in Kenya and KCSE chemistry mean-scores have also been low, over the years.

From these results, it is evident that in most of the years, chemistry registered mean scores of below 30%, implying that most learners have not pursued STEM-related careers associated with chemistry and thus North-Rift Region and the entire nation will not have enough engineers, medical doctors, nurses and other science-related professionals despite the introduction of STEM education programme in schools.

Various researchers have conducted studies on STEM subjects and factors influencing performance among students. Sanchez (2019) evaluated robotics, a product of STEM education programme and established that robotics influenced students' interest in STEM subjects leading to improved students' performance; Nelisa (2022) conducted an evaluation of STEM in Physics in Nairobi Metropolitan Region; Dzana (2012) established that lack of science equipment had contributed to the decline in students' academic performance in sciences while King'onia et al. (2017) established that schools' climate was not inviting and negatively affected students' academic performance.

The reviewed studies have focused on other subjects with minimal attention specifically made to chemistry. Focus has also been made on teaching/learning resources and school climate on learners' performance. No study on STEM and STEM education has been done in the Counties in the North Rift Region. this study therefore examined the influence of Science Technology Engineering and Mathematics (STEM) education programme on students' performance in chemistry in extra-county secondary schools in North-rift region in Kenya.

Research Question

1. What is the effect of of STEM education programme on students' performance in chemistry in extra-county secondary schools in North-rift region in Kenya
2. Does gender influence students' chemistry performance in extra-county secondary schools in the North-Rift Region in Kenya?

Research Hypothesis

1. There is a difference in the chemistry performance of students in STEM and non-STEM schools in extra-county secondary schools in the North-Rift Region, Kenya.
2. There are differences in Chemistry performance between male and female students.

Theoretical Framework

Social Learning Theory by Albert Bandura (1975) guided the study. This theory emphasises that students interact, make observations during the learning process and imitate the characters/behaviours of their colleagues. According to the Social learning theory both cognitive and environmental factors combine and influence student learning and modify their behaviour from the observations in the learning environment. The theory recognises that after learning something, it may or may not result in students' change in behaviour or character. Bandura observed that students learn from one another and copy characters they have observed among themselves. Students will consequently develop positive behaviours and character learnt from one another. STEM education programme championed collaboration and teamwork among students to learn from one another as also noted in the Social Learning Theory.

Research Design and Methodology

Research Design

Sileyew (2020) defined a research design as a framework that guides how research will be conducted. It is a blueprint for data collection, analysis and interpretation to gain answers to evaluation questions. Mixed methods evaluation paradigm was adopted. This study employed convergent mixed methods evaluation design where causal comparative *ex post facto* design was used in the quantitative study while grounded theory design was utilised in the qualitative study. Convergent mixed methods design allowed the evaluator to collect both quantitative and qualitative data simultaneously which were then analysed separately and the results were compared to confirm or disconfirm each other as observed by Creswell and Creswell (2018). Both quantitative and qualitative studies were conducted concurrently to examine the extent of implementation of STEM in chemistry in public secondary schools in North-Rift Region, Kenya.

Causal comparative *ex post facto* design was used to conduct the quantitative study since both the cause and the effect were examined after they had occurred without manipulating the independent variable. Implementation of STEM in the concluded study was the independent variable while students' performance in chemistry was the dependent variable. The inception of STEM in schools was perceived to have had effects on the students' performance in chemistry and hence information on implementation of this programme and its effect on students' performance in chemistry was therefore established through the research.

Grounded theory design was used in the qualitative aspect of the study. Qualitative data on the effects of STEM on chemistry performance were collected in STEM and non-STEM schools and comparisons were made. Through Grounded theory, teaching methods used by teachers and the quality of their lessons were evaluated and their effects were associated with students' performance in chemistry. Emphasis was made on the use of inquiry-based learning, problem-based learning and project based learning techniques which were championed through STEM education programme under implementation in schools. The findings obtained from the qualitative study supplemented those obtained from the quantitative study.

Target Population

The target population consisted of 6 counties and 25 extra-county secondary schools in the North Rift Region. Extra-county schools were selected because they had implemented the STEM education program. Of these 25 schools, 9 were girls' schools, 16 were boys' schools, 12 were STEM model schools, and 13 were non-STEM schools. In total, 1,620 form 4 students were enrolled in STEM schools, and 1,930 were in non-STEM schools, making a total of 3,550 form 4 students. This group was chosen because they had the most extensive exposure to the STEM programme compared to other grade levels, making them suitable participants for the study.

175 teachers of chemistry and 25 principals were also targeted. Teachers of sciences and mathematics in STEM schools were trained in STEM education in mathematics and sciences and they were to implement the skills learnt in their schools. The teachers therefore possessed information regarding the extent of implementation of STEM programmes and hence they were targeted. Principals of STEM schools were also trained on their roles regarding supervision of implementation of STEM programmes. They therefore possessed the information on STEM implementation in schools and hence were suitable to participate in the study.

Sample and Sampling Procedures

Simple random sampling technique was used to select four of the six counties in the North-Rift Region. This method ensured that each county had an equal chance of being included in the study. To ensure representative sampling within each selected county, stratified random sampling was employed to categorise schools into STEM model and non-STEM schools. Since two schools per county were identified as STEM schools by the Ministry of Education, a total of eight STEM schools (four boys' and four girls') were selected through purposive sampling to form one stratum. The remaining 11 non-STEM schools were further stratified into boys' and girls' schools to ensure equal representation based on gender. From each stratum, simple random sampling was used to select four boys' schools and four girls' schools, resulting in a total of eight non-STEM schools. This process yielded a sample size of 16 schools, comprising eight STEM and eight non-STEM schools.

Form four classes were selected by purposive sampling technique since they had interacted with STEM education programme for the longest period of time. Each of the extra-county schools had at least two streams at form four. Simple random sampling was used to select one stream of form four class in each of the selected schools to participate in the study to arrive at a total of 16 streams. Simple random sampling technique gave each stream an equal chance of being selected and hence was a suitable method. Each stream had between 40 and 75 students.

From the selected streams, the number of students sampled from STEM schools was 521 out of 1620 and 519 students were sampled out of 1930 students in non-STEM schools. A total of 1040 students were therefore sampled out from a population of 3550 to participate in the study. Mugenda and Mugenda (2013) observed that a representative sample of 10 % to 30 % of the population is suitable for a study. The sample of 1040 (29.3 %) students was therefore a good representation of the entire student body in extra-county secondary schools in North Rift Region.

Due to the varied distribution of chemistry teachers, three to six teachers in each of the sampled schools (STEM and non-STEM) were selected purposively to participate in the study. A total of 52 out of 175 teachers of chemistry were selected, comprising 30 teachers from STEM schools and 22 from non-STEM schools as schools had varied teachers distributed with a larger population from STEM schools. 16 principals of the selected schools were also selected purposively to participate in the study. They were included automatically because the schools they head had been selected.

Research Instruments

A structured questionnaire was used to collect data from students. The questionnaire was preferred in this method because it was very efficient, less costly, required less time and allowed the collection of data from a wide population within a short period. An interview guide was used to obtain detailed data on implementation of STEM from principals. A lesson observation schedule was used to collect data on the teaching-learning process during chemistry lessons.

Validity of the Research Instruments

Research experts were requested to examine the validity of the research instruments' results. They examined face and content validity of the research instruments. The questionnaires were pilot-tested to a selected sample of respondents from two schools within Rift Valley region.

Reliability of the Instruments

Test-retest method was used to test for the reliability of the rating scales in the teachers', students' questionnaires. Split half method was used to examine the reliability of the lesson observation schedule. The researcher used the two sets of results to compute Pearson product moment correlation coefficient and found to be 0.81 and 0.71 for students' questionnaire and lesson observation schedule respectively. The items in the instruments of data collection were therefore considered reliable since they yielded a correlation coefficient greater than 0.6 according to Mugenda, (2003). Research experts from The Catholic University, Gaba Campus examined dependability, credibility, conformability, transferability and trustworthiness of the evaluation findings from the interview guide.

Results

Students' Performance in Chemistry from the Chemistry Achievement Test

A chemistry achievement test was administered to form 4 students in the selected schools. The total mark which was to be scored by students was 30. Table 1 shows the summary of the findings obtained.

Table 1

Mean Scores for Chemistry Achievement Test by Category of Schools

Category of School	Mean	n	SD
STEM	21.68	521	6.17
Non-STEM	19.06	519	7.15
Overall	20.37	1040	6.80

The findings show that the chemistry mean for STEM schools (21.68) was higher than that of non-STEM schools (19.06). The findings on students' performance in chemistry achievement test were good with students in STEM schools performing better than those in non-STEM schools. The standard deviations were 6.17 and 7.15 for STEM and non-STEM schools respectively. Based on the findings in Table 1, it is evident that the standard deviation for STEM schools was 6.17 was lower than that of non-STEM schools which was 7.15. The standard deviations were large to imply that each of the students' scores in both categories of schools deviated greatly from the respective mean scores.

The findings on mean scores in the two categories of schools may be attributed to positive students' attitude towards chemistry in STEM schools which might have been influenced by teaching methods, motivation methods, and the variation of the adequacy of chemistry resources as observed by Okoth et al. (2018) who established that inadequate instructional resources significantly affected students' performance in science subjects. Students' motivation level also contributes to varied students' performance as observed by Chan and Norlizah (2017) that students' motivation towards science learning had a significant relationship with students' achievement in science.

Test of Hypothesis

H_{01} : There is no significant difference in the mean chemistry scores of students in STEM and non-STEM schools in extra-county secondary schools in the North-Rift Region, Kenya.

H_{A1} :There is a significant difference in the mean chemistry scores of students in STEM and non-STEM schools in extra-county secondary schools in the North-Rift Region, Kenya.

To examine the difference in mean scores between STEM and non-STEM schools, an independent t-test was conducted. The findings are presented in Table 2.

Table 2

T-test for Difference between School Category and Mean Chemistry Performance Scores

School Category	n	Mean	SD	t-value	Sig.Value
Sig. Value	521	21.68	6.17	6.32	0.00
STEM	519	19.06	7.15		
Non-STEM	1040	20.37	6.80		

As shown in Table 2, the t-value was 6.32, and the p-value was 0.00. Since the p-value (0.00) was less than the significance level of 0.05, the null hypothesis was rejected.

This indicates a significant difference in chemistry performance between students in STEM and non-STEM schools. This finding suggests that the school a student attends influences their chemistry performance, possibly due to variations in the availability of teaching and learning resources. Gaotlhobogwe (2012) noted that inadequate resources can negatively impact students' attitudes and perceptions toward subjects like design and technology. The difference in mean scores may also be attributed to the additional Chemistry resources provided to STEM schools by CEMASTEA, which could have given these schools an advantage.

H_{02} : There is no significant difference in mean chemistry scores between male and female students.

H_{A2} : There is a significant difference in mean chemistry scores between male and female students.

To investigate gender differences in Chemistry performance within STEM and non-STEM schools, an analysis of students' scores on the Chemistry CAT was conducted. The findings are presented in Table 3.

Table 3

T-test Table for Difference between Student Gender and Mean Chemistry Performance Scores

Student Gender	n	Mean	SD	t-value	Sig.Value
Boys	525	21.03	6.69	3.19	0.00
Girls	515	19.69	6.86		
Overall	1040	20.37	6.80		

Summary, Conclusions, and Recommendations

Summary

Using a causal comparative *ex post facto* research design and guided by Social Learning Theory, the research targeted 3,550 form four students and 175 chemistry teachers. It employed simple and stratified random sampling to select 1,092 respondents from six counties. Data collection involved document analysis and a chemistry achievement test, with reliability checked via test-retest. Results indicated that students in STEM schools performed better in chemistry compared to those in non-STEM schools. Additionally, boys performed better than girls, confirming a significant gender difference in chemistry performance. These findings align with previous studies showing male students

Conclusion

Based on the findings of the study, it can be concluded that the implementation of STEM education programme has a positive impact on student academic performance in chemistry, particularly in extra-county secondary schools in the North-Rift Region of Kenya. The study demonstrated a significant difference in chemistry performance between students in STEM and non-STEM schools, with STEM students achieving higher scores. Furthermore, the research revealed a gender gap in chemistry performance, with male students outperforming female students.

Recommendations

Based on the findings and conclusion of this study, the Ministry of Education should allocate funds to STEM schools to construct innovation rooms (makerspace) to facilitate students in designing science and mathematics projects. This is also in line with STEM as a pathway in the new education system (CBC) whereby STEM schools should be equipped in preparation to receive students at Grade 10. Students' projects will also be stored in a makerspace/innovation room for future use.

The Ministry of Education should develop strategies to address the gender gap in STEM education and encourage more girls to participate in STEM programmes. This could involve providing gender-specific mentorship, offering role models, and creating inclusive learning environments.

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