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Effectiveness of Science Technology Engineering and Mathematics (STEM) Programme in Improving Chemistry Academic Achievement of Students in Public Extra-County Secondary Schools in the North-Rift Region, Kenya

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The study aimed to establish the effectiveness of STEM education in chemistry in extra-county secondary schools in North-Rift Region, Kenya. The study was anchored on Social Learning Theory. Convergent mixed methods research design was applied. The target population was 3550 form four students, 175 teachers of chemistry and 25 principals. Stratified, simple random and purposive sampling techniques were used to sample out 1108 respondents consisting of 1040 students, 52 teachers and 16 principals. Data were collected using a questionnaire, an interview guide and a lesson observation schedule. Reliability of the research instruments was examined using test-retest and split-half methods. Quantitative data were analysed using descriptive statistics and hypothesis was tested using the Chi-square test. Qualitative data were analysed using themes and presented in form of narratives and direct quotations. The study findings revealed that STEM education programme had been implemented in schools, evidenced by chemistry experiments carried out during lessons; good class organisation and safety of students noted in schools. Hypothesis results established that chemistry resources were evenly distributed in schools hence making school climate inviting. The study concluded that STEM education programme had been effectively implemented in public extra-county secondary schools in North-Rift Region, Kenya. The study recommends that the Ministry of Education should construct an innovation room (makerspace) in each STEM school to assist students in designing chemistry projects and storing them safely.

Keywords: Extra-county, STEM, Chemistry Resources, North Rift Region, Social Learning Theory

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. Students' discipline will improve and learner enrolment 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 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 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 their 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 the Nairobi Metropolitan Region, Dzana (2012) established that lack of science equipment had contributed to the decline in students' academic performance in sciences. King'oina 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 North-Rift Region. This study therefore examined the effectiveness of STEM education programme on students' performance in chemistry in extra-county secondary schools in North-Rift Region, Kenya.

Research Question

To what extent is the STEM education programme effective in improving chemistry academic achievement of students in public extra-county secondary schools in the North-Rift Region, Kenya?

Research Hypothesis

Teaching and learning resources are evenly distributed in public extra-county secondary schools in North-Rift Region, Kenya.

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 consequently resulting in improved academic performance. 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 utilized in the qualitative study. Convergent mixed methods design allowed the evaluator to collect both quantitative and qualitative data simultaneously which were then analyzed 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 was 6 Counties comprising 25 Extra-county secondary schools in North Rift Region. Extra-county schools were targeted since STEM education programme was implemented in these schools. Out of the 25 extra-county schools, nine were girls' school categories while 16 were boys' school categories. 12 schools were STEM model schools while 13 were non-STEM schools. The total number of form 4 students in STEM schools was 1620 and 1930 students were in non-STEM schools. A total of 3,550 form 4 students were therefore targeted, whereby 2125 were boys and 1425 were girls. The reason why form 4 students were targeted was because they had interacted with STEM programme for the longest period as compared to other students in other forms and therefore were appropriate to participate in 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 and hence they were targeted. Principals of STEM schools were also trained on their roles regarding supervision of implementation of STEM . 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 out of six Counties in North-Rift Region. This sampling method was appropriate since it gave every County an equal chance of being selected to participate in the study. To ensure representativeness of schools in each of the selected counties, stratified random sampling was used to categorise schools into two: STEM model and non-STEM schools. Since two schools had been identified by Ministry of Education as STEM schools in every County, a total of 8 STEM schools were identified by purposive sampling to form one stratum, consisting of 4 boys' and 4 girls' schools. The other stratum consisted of 11 non-STEM schools and stratification was further done to categorise them into girls' and boys' school categories as this approach gave each school, based on gender, an equal chance of being selected. From each stratum, simple random sampling was then used to select 4 boys' schools and 4 girls' schools totalling 8 non-STEM schools to participate in the study. A sample size of 16 schools was therefore obtained to participate in the study, comprising 8 STEM and 8 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

Effectiveness of STEM Education Programme in Extra-County Schools

The researcher collected data on STEM implementation from students, teachers, and principals of STEM and non-STEM schools. According to the STEM education program rolled out in STEM schools, the 5Ps (people, place, policy, programmes, and processes) contributed to the school climate, determining whether it was inviting or disinviting (CEMASTEA, 2017).

"People" refers to all school stakeholders, including students, teachers, essential staff, principals, and parents. Place pertains to the environment where learning occurs. Policy refers to the established standards guiding school operations. Programmes encompass the activities taking place at school, while processes involve the way these activities are conducted.

As shown in Table 1, a mean implementation score of 4.16 and 3.90 for STEM and non-STEM schools respectively were obtained. This was in regard to the extent of learner involvement in chemistry experiments. The standard deviations were 0.93 and 1.04 respectively. The mean score was higher in STEM schools than in non-STEM schools. The standard deviation in STEM schools was smaller than that in non-STEM schools. The finding implied that students' views on the aspect of the use of experimentation closely surrounded the mean value in STEM than in non-STEM schools. The finding indicated that teachers exposed their learners to experiments in chemistry more often in STEM as compared to non-STEM schools, leading to varied mastery of content by learners and consequently influencing learner performance in chemistry in a manner that students who were exposed to experiments tended to perform significantly better than those learners taught theoretically.

Experimental approach is a learner-centred approach that allows learners to link the findings obtained to what they have learnt in theory and hence influence their academic results as observed by Lai (2018) college students were very satisfied with the STEM education learning program where inquiry-based learning approaches were used. The findings on the use of experiments as presented in Table 1 were supported by interview reports from principals. One principal from STEM boys' school said that "both teacher-centred and learner-centred methods are employed." Team teaching is

Table 1

Score of Students' Responses on STEM Implementation in Schools

STEM Activity	STEM Schools			Non-STEM Schools		
	n	Mean	SD	n	Mean	SD
Exposing learners to experiments in chemistry	521	4.16	0.93	519	3.90	1.04
Encouraging learners to report their findings in experiments	521	3.85	1.08	519	3.72	1.13
Providing safety during chemistry practicals	521	4.07	1.10	519	4.03	1.16
Ensuring proper waste management during chemistry practicals	521	4.02	1.10	519	3.82	1.22

also in use, project based learning approaches are utilised to move scientific skills. Small group discussions are also in use" (Principal 15, Interviewed on 2nd November 2022).

With regard to the provision of safety by teachers to learners during chemistry practicals, a mean implementation score of 4.07 and 4.03 were obtained in STEM and non-STEM schools respectively while the corresponding standard deviations were 1.10 and 1.16. The mean response from STEM schools was slightly higher than of non-STEM schools implying that chemistry teachers provided safety to learners in STEM schools more often than of non-STEM schools. The same finding was established when the researcher observed chemistry teachers as they conducted lessons. The teachers scored higher in class organisation which promoted good safety in STEM schools than in non-STEM schools. The findings indicated that the school climate in STEM schools was more inviting than in non-STEM schools. The reason that was attributed to the finding was that through STEM education, administrators had acquired skills on how to make their schools inviting because emphasis was made on the general school organisation and learner safety, especially in the laboratories (CEMASTEA, 2017). The finding was in line with Cox (2017) who had established that the quality of a school was measured by how happy the students were. The author had observed that if teachers were not concerned with how their students felt then the school climate was likely to be disinviting. Nelisa (2022) also revealed that school climate characteristics positively influenced students' academic achievement in physics. The standard deviations were high and differed by a slight margin, with that of STEM schools being smaller than that of non-STEM schools which meant that individual scores of respondents towards safety aspect were closer to the mean in STEM than in non-STEM schools.

On the extent to which teachers ensured proper waste management during chemistry practicals, the implementation mean scores of 4.02 and 3.82 which were obtained by respondents in STEM and non-STEM schools respectively. The finding meant that the mean implementation score on waste management in STEM schools was higher than in non-STEM schools. The results meant that teachers in STEM schools ensured proper waste management during chemistry practicals more often than their counterparts in non-STEM schools. The finding might be attributed that teachers in STEM schools had been trained on waste management and awareness of environmental conservation during STEM training. Similar findings were noted during the lesson observations whereby teachers in STEM schools observed waste management better than teachers in non-STEM schools. The finding was in agreement with the recommendation of CEMASTEA (2017) that established STEM schools should focus on improving their climate and make it inviting. More emphasis was placed on improving classroom climate, especially the laboratories and also as established by Ntemngwa and Oliver (2018) who identified the need to provide a supportive and conducive learning environment in schools.

Distribution Rates of Chemistry Resources in Schools

Data on the distribution rates of chemistry resources in STEM and in non-STEM extra-county secondary schools in North Rift Region was established. Chi-square test was used to examine the rate of distribution of teaching/learning resources in schools. The findings were presented in Table 2.

Tests of Hypotheses

The following hypotheses were tested at 0.05 significance level:

- H_{01} : Teaching and learning resources are not evenly distributed in public extra-county secondary schools in North-Rift Region, Kenya.
- H_{A1} : Teaching and learning resources are evenly distributed in public extra-county secondary schools in North-Rift Region, Kenya.

The hypothesis was tested using Chi-square test. Results are presented in Table 2.

The Chi-square value obtained was 230.23 and the p-value was 0.00. The p-value (0.00) was less than the significance level of 0.05 and this was evidence to reject the null hypothesis and hence the null hypothesis that teaching

Table 2

Chi-Square Table of Distribution Rates of Teaching/learning Resources

	Adequacy of Chemistry Teaching/learning Resources
Chi-Square	230.23
Df	4
Asymp. Sig.	.00

and learning resources are not evenly distributed in public extra-county secondary schools in North-Rift Region, Kenya was therefore rejected. The finding implies that chemistry teaching/learning resources are evenly distributed in schools and hence have a similar impact on students' performance in chemistry as observed by Kimeu et al. (2015) that students' academic performance depended on teaching/learning resources including classrooms, laboratory apparatus and chemicals, teachers' and students' reference books. Nelisa (2022) also established that student academic achievement in physics was affected by the characteristics of the school climate.

Summary, Conclusion and Recommendations

Summary

The study aimed to establish the status of implementation of STEM education in chemistry in extra- county secondary schools in North-Rift Region, Kenya. Data were collected using a questionnaire, an interview guide and a lesson observation schedule. Reliability of the research instruments was examined using test-retest and split-half methods. Quantitative data were analysed using descriptive statistics and hypothesis was tested using the Chi-square test. Qualitative data were analysed using themes and presented in form of narratives and direct quotations.

Conclusion

Based on the findings of the study, it was concluded that STEM education programme had been effectively implemented in extra-county secondary schools in North-Rift region, Kenya. This was evidenced by STEM activities noted to have been put in place in STEM and non-STEM schools. Chemistry teaching/learning resources are evenly distributed in public extra-county secondary schools making the school climate inviting.

Recommendations

Based on the findings and conclusion of this study, students should initiate STEM activities during club days. This will enable them to design and improve the quality and quantity of chemistry projects hence enhancing creativity and innovation.

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