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Evaluation of chemistry performance in secondary schools in nomadic pastoralist communities of Kajiado and Narok counties in Kenya

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Abstract

The study assessed level of training of staff, skills gap, physical facilities and socio-economic factors affecting teaching and learning of chemistry in secondary schools in Narok and Kajiado counties in Kenya which have a large population of nomadic pastoralists. The study involved 20 teachers, 10 technicians and 196 students from 19 schools. Data was collected using questionnaires, observations and oral interviews. The results showed that schools in both counties experienced growth in student enrolment between 2013 and 2017 without a matching increase in facilities and resources for curriculum implementation and evaluation. All the teachers were qualified to teach in secondary schools, however, the average teacher to student ratio in both counties was 1:137 way above the recommended 1:40. The data indicates that the performance in chemistry has been declining in the national examination with 81% of the candidates scoring 31% and below. The poor performance is attributed to inadequate number of teachers and technicians, inadequate laboratory facilities and student absenteeism due to socio-cultural practices. The results indicate an urgent need to address the causes of the declining performance in chemistry.

Keywords: Nomadic pastoralists, chemistry curriculum, chemistry examination, laboratory facilities, socio-economic practices

1. Introduction

The Kenyan education system comprises basic and higher education. Basic education is composed of primary and secondary schools. Secondary schools are categorized into sub-county, county, extra-county and national schools. Secondary schools education takes four years (Form I to Form IV). Depending on the population of the school, a form maybe divided into streams, each of which should have a maximum of 40 students. Mathematics, Chemistry, Biology and Physics are the main Science, Technology, Engineering and Mathematics (STEM) subjects taught in secondary schools. Mathematics is a compulsory subject and students are required to study at least two out of the other three science subjects. The government of Kenya has placed great importance on the STEM subjects with the aim of producing a workforce with technical skills to enable the realization of Kenya's development blueprint, Vision 2030 (Ministry of Planning and National Development, Government of Kenya, 2007). The implementation of STEM curriculum is met with challenges especially in nomadic pastoralist areas (Aruan *et al*., 2016). Learners from nomadic pastoralist communities are faced with peculiar challenges in continued access to education (Raymond, 2020; Shani, 2020). This is because education programs and curriculum delivery services in Kenya are designed for fixed schools where learners take lessons in classrooms in permanent locations. Nomadic pastoralists do not establish permanent settlements and have seasonal migratory patterns to destinations that depend on the availability of pastures and water for their animals (Hussein, 2016; Ng'asike, 2019). As a consequence, the performance of these subjects at the national exams has been very poor (Menjo, 2013).

Chemistry is a practical subject which develops hands-on skills in the learners necessary to write national examinations successfully. These skills are useful when the students proceed for further training at the university or technical training institutes to prepare them for the real world (Welle-Strand and Tjeldvoll, 2003; Tomasevic and Trivic, 2014). The examination of chemistry at the national level involves theory paper (TP) and practical paper (PP) which accounts for 40%

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and 60% respectively, of the final grade. Effective teaching of chemistry requires adequate teaching facilities and personnel including science laboratories, equipment, trained science teachers and technical staff. The science laboratories are designed for fixed schools, making nomadic students lack access to them once they move to new areas (Ng'asike, 2019). Investment in educational infrastructure is lacking and more so for science based subjects. The socio-economic and cultural practices among the nomadic pastoralist communities present a considerable impediment to the delivery of quality education and the secondary school completion rates (Abdi, 2010; Dyer, 2016). In recognition of these gaps, the government of Kenya formed National Council for Nomadic Education in Kenya (NACONEK) that is expected to develop policy framework for educational development, resource sharing, improvement of training facilities and public participation (MoEST, 2015).
Provision of adequate physical facilities motivates students to learn (MoEST, 2015). A study conducted in Greece has shown that the level of motivation in students is a good predictor of their performance in chemistry (Salta and Koulougliotis, 2015). Therefore, motivation coupled with the deployment of student-centered learning (Demirdogen and Cakmakci, 2014) and best practices in student evaluation (Harshman and Yezierski, 2015) have the potential to improve performance in chemistry. Trained teachers are able to adapt the content, teaching and evaluation methods to the benefit of the students (Chen and Wei, 2015). This should be done in a way that will attract the student interest to the subject. Science curricula that do not focus on the interests of the students may not motivate them and thus tempers their curiosity (Glenn, 2000; Osborne *et al*., 2003). The use of locally available materials could bring out the curiosity of the students and drive the interest of the students in chemistry. Some of the locally available materials that can be used to design and develop experiments include; wood ash, fruits and plant extracts (Tomasevic and Trivic, 2014).

The aim of this study was to evaluate the level of training of STEM teachers and technicians, physical facilities, socio-economic aspects of nomadic pastoralist communities in Narok and Kajiado counties of Kenya. The study also determined the effects of the above factors on the teaching and learning of chemistry in selected secondary schools in these counties. These counties were selected as representatives of the nomadic pastoralist communities in Kenya.

2. Methodology

2.1 Study Sample

The study was conducted in 19 public secondary schools; 10 from Kajiado County and 9 from Narok County. The two counties were selected because they have a large population of nomadic pastoralists. All the schools were purposively selected based on the nomadic pastoralist setting. Before the study, permission was sought and granted by the school principals to collect data from the teachers, technicians and students. The participants were informed about the aims of the study prior to the administration of the questionnaires and consented to participate in the study. A total of 20 teachers and 10 technicians responded to staff questionnaire while 196 students responded to the students' questionnaire. In each school, a minimum of 10 students in forms three (3) and four (4) were selected to respond to the questionnaire.

2.2 Data collection and analysis

Quantitative and qualitative data was collected from the respondents. Quantitative data was obtained by use of questionnaires to assess the needs, knowledge and skills gap in chemistry education in Kajiado and Narok counties. Two sets of questionnaires were administered: a) Administration (principals or deputy principals) and teachers (heads of department of science, chemistry teachers and technicians) questionnaire which was provided to the schools in advance and b) student questionnaire which was administered during school visits by the research team.

Some questions were structured to provide definitive/specific answers while others were open ended. There were no Likert-scale type questions. The questions were designed to obtain information on the schools, school's community characteristics, student population, number of science teachers, number of chemistry teachers, number of chemistry technicians, teacher and technician qualifications, number of students taking Kenya Certificate of Secondary Education (KCSE) chemistry examinations from 2013 to 2017, science infrastructure, modes of evaluation for Chemistry subject, frequency of practicals/experiments per term, use of locally available materials for chemistry practicals and chemical waste disposal practices. Data on chemistry performance from 2013 to 2017 were obtained from the Kenya National Examinations council (KNEC) for the two counties.

Qualitative data was also collected from the respondents through oral interviews as well as classroom and laboratory observations. School head teachers, chemistry teachers, technicians and students were interviewed. These interviews were open and structured with the aim of obtaining more information regarding physical facilities, teaching and learning, socio-economic, cultural and other factors affecting students' performance in chemistry. Moreover, observations of physical infrastructure, class size, school environment and other factors affecting teaching and learning in the locality were made. Statistical analysis of the data obtained was performed using MS-Excel, Statistical Product for Service Solutions and SigmaPlot.

3. Results and Discussion

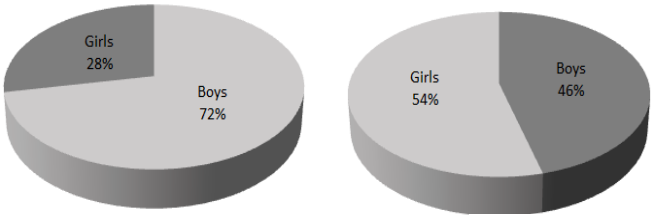
3.1 Student population

The 19 schools surveyed comprised 15 sub-county schools, 1 county school and 3 extra-county schools. The schools were a combination of boys boarding, girls boarding and mixed boys/girls day schools. Of these schools, 14 had more than one stream of classes from Form I to Form IV. Only one school of the sampled schools in Kajiado County had 7 streams while

two schools in Narok County had 6 streams and the rest of the schools had between 1-4 streams in the 2018 Form I intake. Table 1 shows the total student population in Form I, II, III and IV in both counties at the time of the survey. The data shows that the Kajiado and Narok schools had a population of 2,690 and 4,751 students respectively from Form I to Form IV. A further analysis of the gender distribution of the student population is presented in figure 1.

Table 1. Total number of students in the schools surveyed in Kajiado and Narok counties

COUNTY	**STUDENT POPULATION**				
	Form I	Form II	Form III	Form IV	TOTAL
NAROK	1645	1106	1048	952	4751
KAJIADO	955	800	516	419	2690
				TOTAL	**7441**



(A) (B)

Figure 1. Gender distribution of the student population in the selected schools in (A) Kajiado (B) Narok counties

Figure 1 shows that there were more boys than girls in Kajiado County at 72% boys and 28% girls. In Narok County, the student population comprised of 46% boys and 54% girls. For the day scholars, the distance from home to school varied from 1 km to 10 km which meant that the students walked long distances to attend school. The low enrollment of girls in Kajiado is partly attributed to the long distances the girls have to walk to access education. This observation has also been made among Maasai pastoralists in Tanzania (Raymond, 2020). In Narok, the communities exhibited more migratory behavior with the young men moving with livestock to areas with pasture during the dry seasons which is indicative of the higher girls enrollment compared to boys.

3.2 KCSE performance in Chemistry from 2013 to 2017 in Kajiado and Narok counties

Chemistry was a compulsory subject in all the schools in this study which implies that chemistry candidature is equivalent to the total KCSE enrollment. The chemistry results in KCSE for schools in both Kajiado and Narok counties from 2013 to 2017 were analyzed from data obtained from the Ministry of Education Science and Technology (MoEST). The study examined the trends in grades A to E (where A is excellent performance with 80% and E is fail with 10%) as well as U (ungraded), X (candidate absent) and Y (results cancelled). During this period, a total of 33,692 candidates in Kajiado County and 26,766 candidates in Narok County were examined in chemistry at KCSE. Table 2 shows the number of KCSE candidates in chemistry between 2013 and 2017 for Kajiado and Narok counties. It is evident from table 2 that both counties recorded progressive increase across the years in the number of candidates who took chemistry at KCSE.

Table 2: Total KCSE candidature in chemistry per year per county

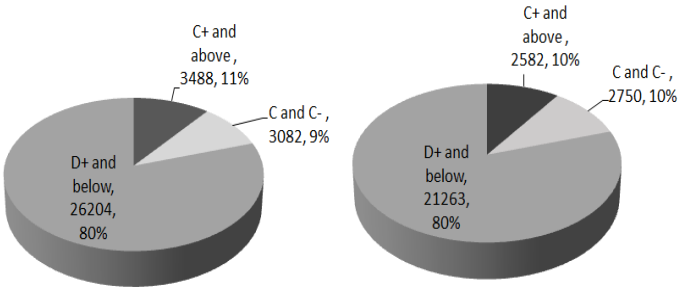
County/Year	**2013**	**2014**	**2015**	**2016**	**2017**	**Total**
Kajiado	5,482	5,900	7,041	7,416	7,853	33,692
Narok	4,214	4,780	5,474	5,865	6,433	26,766
Total	**9,696**	**10,680**	**12,515**	**13,281**	**14,286**	**60,458**

This is an indication that the counties exhibited increased school enrolment attributable to the introduction of free basic education in Kenya in 2003. It is also noted from table 2 that the candidates in Narok County are fewer in each year than those in Kajiado County.

3.3 Distribution of Chemistry grades in the counties

In Kenya, the minimum entry mean grade to the university is C+ for an undergraduate degree while that for a diploma course is C, and a C- for a certificate course. Besides the minimum entry requirements, chemistry related courses at the university require at least grade C+ in chemistry. Similarly, to be trained as a chemistry teacher, one must have scored a minimum grade of C+ in chemistry at KCSE.

In analyzing the chemistry grades, it is important to determine the number of candidates that qualify to pursue chemistry related courses at the universities or middle level colleges. A total of 60,458 candidates in the two counties sat for the KCSE chemistry examination between 2013 and 2017 (Table_S2 & Table_S3_SuppInfo).The grade distribution as scored by these candidates were: C+ and above, 6,070 (10.04 %); C and C-, 5,832 (9.65 %); D+ and below, 47,467 (78.51 %). The number of candidates who registered but did not write the chemistry examination were 481 (0.80 %) while 608 (1.00 %) had their results cancelled for irregularities. The distribution of the chemistry grades per county is shown in figure 2.



(A) (B)

Figure 2. Distribution of Chemistry grades for five years in (A) Kajiado and (B) Narok Counties

In Kajiado County, out of the 33,692 candidates, 3,488 scored grades C+ and above. This implies that only 10.35% of the candidates in the 5 year period qualified to pursue chemistry related courses at the university. A further 3,082 (9.15 %) scored grades C and C- and qualified to pursue certificates and diplomas in chemistry related courses in technical and vocational institutions. The remaining 27,122 (80.50 %) scored D+ and below and therefore do not qualify for any chemistry related courses at post-secondary level. In Narok County, the number of candidates who scored C+ and above in chemistry were 2,582 (9.65%), C and C- 2,750 (10.27 %) while those who scored D+ and below were 21,434 (80.08 %).

Data from both counties show that grades D+ and below were significantly high in the period 2013-2017 compared to other grades (Supporting Information Table S1). The poor performance can partly be attributed to absenteeism from school. From the student responses, 89% of the students reported to have been absent from school at least once in 2017. Of these students, 71% cited lack of school fees as the major reason for being absent. Other reasons for absenteeism included inaccessibility of schools during rainy seasons and cultural practices such as circumcision. Due to declining number of students who qualify to pursue chemistry related courses, there will be few chemistry professionals in future.

3.4 Number of Science Teachers and their qualifications

The 10 schools surveyed in Kajiado had 48 science teachers while the 9 schools in Narok had 69 teachers. It is important to note that the teachers teach a combination of any two of the following subjects; Mathematics, Biology, Chemistry and Physics. Out of the 117 teachers in both counties, 63% were employed by the government through the Teachers Service Commission (TSC) while 30% were employed by the school Board of Management (BOM). There were 5% trainees on teaching practice and 2% volunteer teachers. The number of teachers from the local nomadic pastoralist community in Kajiado and Narok Counties was 7 and 22 respectively. This indicates that from the schools surveyed, 85% of the teachers in Kajiado and 68% in Narok were drawn from other communities.

The data further revealed that out of the 117 science teachers in both counties, only 57 (49%) teach chemistry. With a population of 7,792 students, the average chemistry teacher to student ratio was 1:137. This is way below the recommended ratio of 1:40 recommended by Ministry of Education (MoEST, 2016). Table 3 shows the specific chemistry teacher: student ratio for each county.

Table 3. Chemistry teacher to student ratios

	County	
	Kajiado	Narok
Number of Students Taking Chemistry	3054	4781
Number of Chemistry Teachers	19	38
Chemistry Teacher : Student Ratio	1:161	1:126

The deficit in the number of teachers in both counties is evident in Table 3. The data shows that a teacher in Kajiado County teaches 4 times the recommended number of students by the government of Kenya (MoEST, 2016). This distortion in the teacher: student ratio impacts negatively on the effectiveness of teaching and learning of chemistry. The number of students taking KCSE chemistry exam consistently increased from 2014 to 2017 (Supporting Information Table S2). For instance, in Kajiado County the number of candidates doubled between 2014 and 2017. This growth in student population was not matched with a corresponding increase in the number of teachers and technical staff.

The qualification of the teachers is an important aspect of content delivery as it affects the quality of teaching chemistry. The qualifications of the teachers in the surveyed schools were; Diploma in Education (Science), Bachelor of Education (Science) and Bachelor of Science with a Postgraduate Diploma in Education. In addition, one teacher had Master of Science (MSc) degree in Chemistry and another had an MSc in Mathematics. The minimum qualification for teaching chemistry in Kenya is a Diploma in Education (Science). Therefore, all the teachers in the surveyed schools were qualified to teach chemistry but had a high teaching load owing to the low teacher: student ratio.

3.5 Number of laboratory technicians and their qualifications

The chemistry curriculum has a practical learning component. This necessitates the involvement of technicians to assist the teachers in delivering the practical component of the chemistry syllabus. The survey established the number of technicians and their qualifications as shown in table 4. There were 13 laboratory technicians in the 19 schools surveyed and 8 schools did not have any laboratory technicians.

Table 4. Number of technicians and their qualifications

	NUMBER OF TECHNICIANS				
COUNTY	**Craft Certificate**	**Diploma**	**Higher Diploma**	**Others**	**TOTAL**
KAJIADO	1	3	0	0	4
NAROK	2	4	3	0	9
				TOTAL	13

The data in table 4 shows that 3 technicians had Craft Certificate which is the minimum qualification required to work in a secondary school laboratory. Of the remaining, 7 had a diploma while 3 had higher national diploma. It should be noted that the technicians serve not only as chemistry technicians but also physics and biology in most of the schools. For the survey period (2013-2017), there was zero growth in the number of technicians employed as shown in figure 3 whilst the number of chemistry teachers and students increased. The low number of laboratory technicians together with the low teacher: student ratio, compromised the quality of delivery of the chemistry curriculum and hence the overall chemistry performance in KCSE.

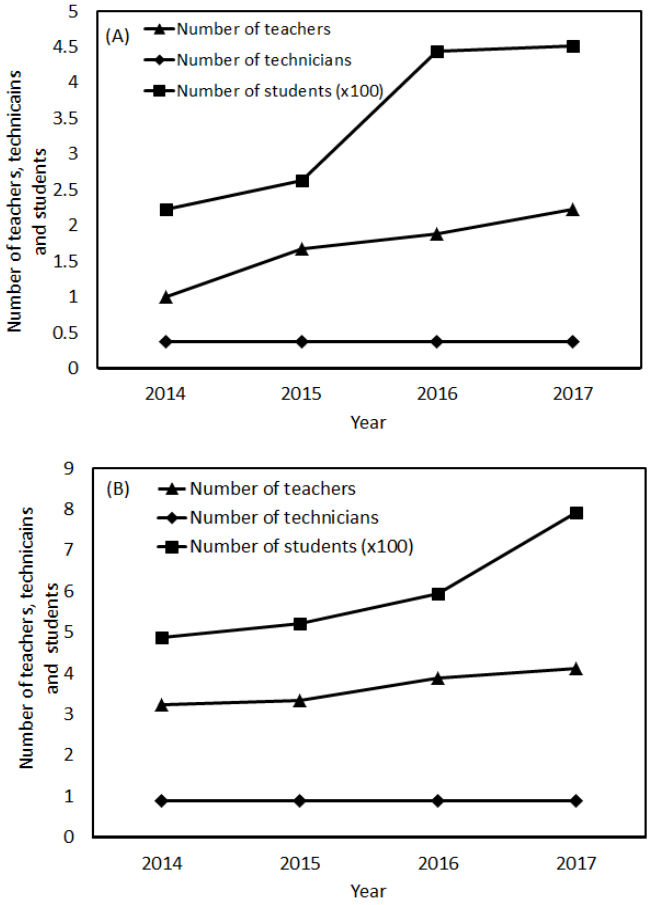


Figure 3. Number of chemistry teachers, technicians and students from 2013-2017 in (A) Kajiado and (B) Narok counties

3.6 Laboratory Facilities

The survey established the number of science laboratories dedicated to the teaching of chemistry, physics and biology. Figure 4 shows the number laboratories in the schools surveyed. There were a total of 11 science laboratories in the 19 schools.

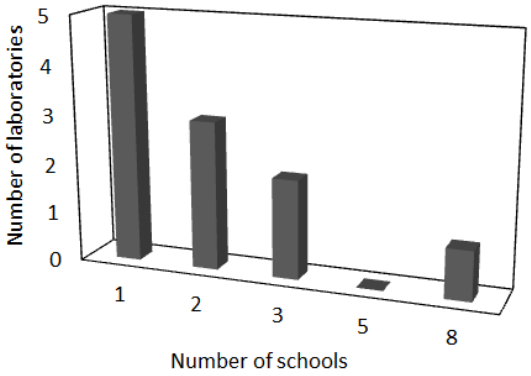


Figure 4. Number of laboratories in the schools surveyed in Kajiado and Narok Counties

The survey also determined the number of laboratories used for teaching the subject combinations; Chemistry/Physics, Chemistry/Biology or Chemistry/Biology/Physics in the 19 schools. The results show that 3 schools from Kajiado County and 2 from Narok County did not have any science laboratories while 8 schools had 1 laboratory used for all the 3 science subjects. Three schools had 2 laboratories while two schools had 3 laboratories. These schools utilized the available laboratories for teaching either Chemistry/Physics, Chemistry/Biology or Chemistry/Biology/Physics. Only one school in Narok County had 5 laboratories with one dedicated for teaching chemistry. In Kajiado County, only one school had a laboratory dedicated to the teaching of chemistry. Sharing of laboratory facilities between schools was reported.

Majority of the schools reported not performing chemistry demonstrations for the students in Forms I, II and III due to lack of chemicals, equipment and laboratory facilities. In addition, the number of individual and group practicals per year ranged from zero to an average of 15 in the schools with laboratory facilities. From this, it is evident that the number of practicals performed by the students was inadequate to prepare them for the chemistry national examination given that the

practical component contributes a higher percentage in the final score. This clearly shows that lack of laboratories and inadequate number of technical staff hampers the effective teaching of chemistry and hence the poor performance.

3.7 Testing and Evaluation of Chemistry

The KNEC chemistry examination format comprises of 3 papers administered at different times during the examination period. Papers 1 and 2 are theory and carry a total of 150 marks while paper 3 is a practical examination of 40 marks. In computing the final grade of the candidate, papers 1 and 2 contribute 25% each while paper 3 alone contributes 50%. It is clearly evident that the practical examination is a crucial component of the final grade scored by a student. Poor performance in the practical examination generally leads to lower grades being attained. Results from the survey indicate that the mode of school-based evaluation of chemistry differed from school to school in terms of the format and frequency of administration of the examinations. It was reported that not all exams followed the KNEC chemistry examination format. All the schools gave theory examinations at all levels (Form I to Form IV). Whereas some schools gave practical examinations to Form III and IV, practical examinations were not administered to Form I and II. The reason was lack of chemicals required for the practicals as well as inadequate laboratory space to accommodate the students during the examination. Some of the schools do not have laboratories in which the practical examinations could be administered. In general, the school-based modes of evaluation for chemistry included assignments, quizzes, random assessment tests, continuous assessment tests, oral examinations, end of term written examinations, practical examinations for the upper classes (Form III and IV), and term opener examinations.

3.8 Use of Local Materials in practicals and Chemical Waste Management

The schools surveyed did not have adequate chemicals required to perform practicals on a regular basis due to inadequate budgetary allocation. Ten (10) schools reported making chemical purchases only once or twice per year leading to chemical shortages, while the remaining 9 schools made purchases at least three times per year. During the time of shortage, the schools reported use of locally available materials as alternatives to the chemicals, reagents and apparatus. Some of the local materials used include: table salt, cartons, boxes, wood ash, groundnuts, paraffin, sand, grass, leaves, flowers, petals, red cabbages, pencil lead, graphite rod, assorted fruits, waste paper, plastic bottles, plastic cans, charcoal stove, cereals mixed with husks, cotton wool, limestone, calcium ammonium nitrate fertilizer, toothpaste, egg shells, lemon juice among others. Some of the practicals that utilize these locally available materials are listed in the **table S3**. There is need to develop standardized practicals using locally available materials in order to mitigate the budgetary constraints. The use of locally available materials will increase the frequency of practicals leading to adequate implementation of the chemistry syllabus. This has the potential of positively changing the attitude of the students towards chemistry (Osborne *et al*., 2003).

Chemical waste management was identified as a major issue of concern in the surveyed schools. The chemistry teachers and the technicians bear the responsibility of managing the chemical waste generated from the laboratories and advising the school administration on proper chemical waste management. In the schools surveyed, the following were reported as the chemical waste disposal methods: Pouring liquid waste and dilute chemicals in pits, open ground or soak pits, disposal of solid chemical waste in dust pits, composite pits, open ground and septic tanks, disposal of broken glass in pits, pouring corrosive waste into the sinks, disposing broken mercury thermometers in pits, burning of plastics and partnering with public health officers to collect and dispose the waste. Partnering with public health officers to collect and dispose chemical waste was the only acceptable chemical waste disposal method in use by the schools. The remaining chemical disposal methods pose a hazard to the environment and human health. These practices point to gaps in the training of teachers, technicians and school administration on chemical waste management best practices. A clearly defined chemical waste management policy framework and enforcement from the MoEST and Ministry of Environment is required in schools. The policy should address chemical waste minimization strategies, handling, disposal and training of staff on chemical management best practices.

3.9 Improving Chemistry Teaching and Performance

The survey results and past KCSE data from 2013 to 2017 indicate declining performance in chemistry with ~80% of the students scoring grades D+ and below. The administration and teachers from the surveyed schools suggested the following measures to improve the teaching and learning of chemistry in the schools: Building of well-equipped laboratories including laboratories dedicated to teaching chemistry, provision of adequate chemicals and laboratory apparatus for practicals, providing adequate staff (teachers and technicians), increasing the number of practicals, practical examinations to be administered every term to improve hands-on training for students, integrating information and communications technology into the teaching and learning of chemistry, provision of audio and visual aids on some technical topics, and encouraging peer-led learning by forming discussion groups. Well-structured outreach activities involving teachers, industry and other institutions have the potential to change perceptions towards science amongst the students (Vennix *et al.*, 2017). The use of student centered approaches is a powerful tool for teaching and learning science (Chin and Osborne, 2008; Demirdogen and Cakmakci, 2014). Other measures include facilitating and empowering chemistry teachers by providing continuous in-service education, training, workshops and talks. This will equip teachers with

the current trends in chemistry teaching methodologies. Academic trips to industries relevant to secondary school chemistry curriculum are also necessary for learners to appreciate industrial applications of chemistry. There is need to encourage student participation in symposia to enhance peer learning which will help students have a better understanding of chemistry.

4. Conclusions

The levels of training of teachers and laboratory technical staff, skills gap, physical facilities for teaching chemistry and socio-economic factors that affect performance in chemistry examination were investigated in selected schools in Kajiado and Narok Counties. All the teachers and laboratory technical staff in the surveyed schools met the minimum qualifications for teaching chemistry in secondary schools in Kenya. However, the chemistry teacher to student ratio is 1:137, implying a high teaching load and consequently ineffective delivery of curriculum. There was low number of laboratory technical staff which compromised the delivery of the practical component of the chemistry curriculum and hence the overall chemistry performance in KCSE. Chemical safety, security and chemical waste management is lacking in teacher and laboratory staff training curriculum. Schools in both counties have experienced increased student enrolment without a corresponding increase in the physical facilities required to implement the chemistry curriculum. Some of the schools did not have laboratories for teaching practical lessons and administering chemistry practical examinations. Low enrolment of girls was observed in Kajiado County due to long home to school distances in the surveyed schools. In Narok, low enrolment and poor retention of boys was observed, attributed to community migratory behavior in which boys move with livestock in search of pastures. These migratory patterns, lack of school fees and other cultural practices resulted in absenteeism and hence poor performance in KCSE. In order to deliver chemistry curriculum in secondary schools effectively and prepare students for STEM careers, interventions are required majorly in physical facility and human resource investments in schools.

Supporting Information

Information including the questionnaires used for this study is available at https://kenyachemicalsociety.org/journals

Conflicts of interest

There are no conflicts of interest to declare.

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