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ORIGINAL PAPER

Teachers' use of class talk interaction as a predictor of learning outcomes in chemistry

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Abstract

There appears to be a general, global trend of many students not taking chemistry related courses at post-secondary institutions, while the academic performance of the subject at secondary level is on the decline. Addressing the performance and unpopularity gaps of the subject requires an exploration of effective pedagogical practices. One critical objective of a chemistry teacher is to create an active learning environment. However, due to insufficient research, relatively little is known about the concept and role of class talk interaction in enhancing learners' engagement and inquiry-related curiosity. To address the gap, the current study explored the effect of class talk interaction on students' learning outcomes in chemistry. The study adopted a descriptive survey design. The study involved a sample of 384 students and 30 teachers, drawn from 30 public secondary schools in Murang'a County, Kenya. Data was collected through validated instruments which included students' questionnaire, interview schedule, observation checklists and also a Chemistry achievement test. Descriptive statistics revealed that learners were very poor in utilizing class talk interaction, in comparison with teachers who were rated above average. Further, inferential statistics involving one way ANOVA revealed that there was a statistically significant effect of class talk on learning outcomes, while simple regression revealed that class talk is a strong predictor of learning outcomes. These results indicate a need for policy interventions aimed at achieving meaningful instructional class talk interaction between teachers and students as a way of improving learning outcomes.

Keywords Class talk · Learning outcomes · Learners' engagement · Pedagogical practices

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Introduction

Quite often, learners fail to understand scientific concepts due to the unsuitable instructional delivery techniques used by teachers (Juan and Lasaten 2016). It has been noted that science teachers must be innovative in creating interesting interactive lessons for meaningful learning experiences to learners if the desired learning outcomes are to be achieved. Gichuru and Wafula (2016) asserted that the quality of learner-teacher interaction in any science classroom setting is the most critical component for closing achievement gaps. Therefore, a teacher may prepare impressive schemes of work, lesson notes and lesson plans but unless an effective instructional delivery technique is used, the objectives of the lesson may not be achieved. One of the strategies in the teaching of sciences that is attracting attention in educational research is class talk interaction (Wong and Wong 2009).

Class talk interaction involves activities such as mentioning students by name, teachers asking students questions and probing the feedback given and engaging students in conversations during the lessons (Fatemeh et al. 2018). Dufresne et al. (1996) referred to class talk interaction as an emerging pedagogy that serves as a catalyst for creating more interactive student-centred learning environments. The method helps the learners to become more actively involved in constructing and using knowledge. It enhances the communication interaction among learners and between the learners and the teacher. Therefore, a characteristic of a class active in class talk involves talking, describing, explaining, cooperative group work, class-wide discussions and interactive lectures. A lesson characterized by a combination of these variables would be expected to enhance learners' engagement and inquiry-related curiosity. Such curiosity is fundamental to meaningful learning.

It has indeed been argued that the more a learner participates through class talk interaction, the more the benefits in terms of learning outcomes (Frymier and Houser 2016). This can be interpreted to mean that class talk is an effective pedagogical instrument that provides a teacher with an opportunity to develop a rich and lively learning environment without losing control of the class. In America, for instance, class talk interaction is highly valued and considered a good indicator of learners' engagement during the teaching and learning process. In Ireland, class talk interaction is given a lot of prominence at every level of primary and secondary school curriculum (Sisquiarco et al. 2018).

The implication is that class talk interaction is perceived by some countries as a way of enhancing learners' engagement during the learning process (Frymier and Houser 2016). Class talk interaction is therefore not a new phenomenon in the learning process, but it is not clear why it is not a popular practice with teachers in many countries. CheeKeong et al. (2014), for instance, revealed that there are many countries in the world that have not incorporated class talk interaction in their national curriculum thus creating a gap between education practice and policy. Some reasons that support these gaps include insufficient, in-depth, empirical studies while the concept of class talk interaction remains unclear to education stakeholders.

Previous studies investigating class talk interaction as a teaching technique reveal different results, vary in their research design or use different data

collection techniques. For instance, studies by Abdallah and Ahmed (2015), Ali and Mahfoodh (2019), Al-Hebaish (2012), Juan and Lasaten (2016), Langeloo et al. (2019) and Tichapondwa (2016) focused on associations or relationships between class talk interactions and quality learning, revealing a positive association between the two variables.

Fatemeh et al. (2018) and Mahmud (2014) studies focused on the influence of class talk interaction on the academic achievement of learners. The two studies revealed that class talk interaction significantly influenced academic achievement. The current study however addressed the effect of class talk on academic achievement of learners as a learning outcome and also addressed the sample gaps noted in Mahmud's study. Further, it used a larger sample size of 384 secondary school students compared to 83 respondents used in the Mahmud study. According to Bryman (2012), the bigger the sample size, the higher the reliability of the data.

The findings of a study undertaken by Sukris (2018) in Indonesia revealed that class talk interaction had a significant positive effect on students' achievement in English. Although the study is similar to the current study, a methodology gap was identified in Sukris' study because teaching methods of sciences and languages differ. Further, the current study used an observation schedule as the main instrument for data collection whereas Fatemeh et al. and Mahmud's studies used a questionnaire which has inherent weaknesses in data collection.

While some studies such as Tichapondwa (2016) adopted a quasi-experiment design and engaged audio-taping of lessons as the main data collection instrument, the current study addressed the research design gap by adopting a descriptive survey design. A quasi-experimental design has its own shortcomings because human beings are likely to behave differently when they are aware that they are being observed for a particular behaviour. Compared to lesson observations, audio-taping of lessons is more distractive to learners during the lessons and is received with suspicion by some learners. To increase the credibility and reliability of the data in the current study, the learners and teachers were unaware of the nature of data collected during the lesson observation.

Although the previewed studies suggested that class talk interaction is beneficial for instruction other than gaps in methodology, the studies do not provide a clear interpretation of the effect of class talk on learning outcomes. Indeed, little is known regarding the use of class talk interaction due to the seemingly few studies conducted. Therefore, there is a need for further in-depth empirical studies to support, strengthen and critique the previous findings. To fill the gaps, the current study proposed that teachers' use of class talk interaction can be a predictor of learning outcomes measured in terms of learners' academic achievements in the subject of chemistry.

Justification of the study

The current study was necessitated by the widespread poor performance in chemistry examinations despite the fundamental role that chemistry plays in advancing and developing a scientific and technological base in the world (Bernardine and

Benedict 2019). According to Wolfgang (2011), chemistry is an unlikely answer given when adults are asked what their favourite subject in school was. Majority of adults most likely remember the poisonous gases prepared in the chemistry laboratory, formulae and manipulation of data, and balancing of chemical equations. This is probably because many of the topics in chemistry are abstract and involve models and theories, thus making the subject appear difficult to learn and master. Previous studies have revealed that the performance in chemistry in several countries globally remains poor. For instance, from the available literature, poor performance in chemistry in developed countries like Australia and USA (Bernardine and Benedict 2019), Germany (Wolfgang 2011) and Israel (Raved and Assaraf 2010) is a growing concern. The same situation was also reported in several African countries: Kenya (Kenya National Examinations Council 2020), Nigeria (Banu 2006), South Africa (Mji and Makgato 2006) and Uganda and Zanzibar (Ahmed et al. 2015).

Indeed, one of the concerns in the USA is evident in the report circulated by the American Chemical Society (ACS) which has created awareness about the role of chemistry in society declining concomitant with a decline in the number of students taking chemistry in high school. According to Bernardine and Benedict (2019), academic achievement in chemistry at secondary level is miserably poor in the USA where chemistry and other science subjects are consistently ranked behind other subjects. According to Scott's (2013) report titled '*Chemistry Makes a Comeback in U.K. Universities and Schools'*, between 1995 and 2005, nearly 30 out of 70 of the U.K.'s chemistry departments closed due to a decline in undergraduate enrolment in chemistry. In response, the government provided USD 550 million through the Higher Education Funding Council for England (HEFCE) for utilization in the academic years 2005–2012 to support what was referred to as 'strategically important and vulnerable subjects', including chemistry. The funds were to be utilized in outreach programs to encourage students to study chemistry at high school and university level. Surprisingly, due to the economic recession that begun in 2008, an increased number of students in the U.K have enrolled for chemistry degrees because of good job prospects provided by the subject. However, a study of ninth-grade students in Germany revealed a marked drop in academic performance in chemistry in the period 2012 to 2018 (Institute for Quality Development in Education 2019).

The widespread poor performance in chemistry requires a constructive response. This is because the technological growth of any nation is determined by performance in sciences and mathematics. Post-secondary courses such as engineering, medicine and food technology enrol students who can perform well in mathematics and other science subjects (Njagi and Silas 2015). According to Education, Science & Technology (n.d), the Africa Union achievement of Aspiration 1 of Agenda 2063 states that, "A prosperous Africa shall be based on inclusive growth and sustainable development". As such, this requires a system to develop human and social capital through an education and skills revolution emphasizing innovation, science and technology.

Evidently, chemistry is generally accepted to be a central science and a requirement in nearly all technological courses. Therefore, to address performance and unpopularity gaps of the subject, an exploration of effective pedagogical practices and re-examination of existing practices is required.

Consequently, based on this background, there is an urgent need for in-depth studies to unearth the causes of poor performance in chemistry. This will help teachers in their professional development as well as improve teachers' knowledge and skills on effective pedagogical techniques. With regard to chemistry education, the variables causing poor performance in chemistry seem not to be very clear; so, it is not easy to discern whether it is the teachers' characteristics, learners' attitudes and methods of instruction or instructional materials that are the problem. This lack of clarity may perhaps have resulted in gaps; limiting the ability of decision and policy makers to proffer appropriate advice to the chemistry educators. In the US, teacher quality was identified as one of the major factors inhibiting science learning in high schools (Bernardine and Benedict 2019). In Israel, findings from a study conducted by Raved and Assaraf (2010) revealed the interpersonal interaction between teacher and student and the diversity of the teaching techniques as the most critical factors towards the achievement of a successful chemistry lesson. Several African countries—Kenya (Kenya National Examinations Council 2020), Nigeria (Nbina 2012) and Zanzibar (Hassan et al. 2015)—have also attributed teaching methodologies as the main cause of poor learners' academic achievement in chemistry.

It is evident from previous research that lack of appropriate interaction techniques could be playing a significant role in inhibiting quality learning in chemistry. The current study therefore proposed that in a class talk enhanced lesson, learners' attention is easily and gently diverted from one task to another. This results in an active lesson with meaningful learning. The researcher hypothesized that effective class talk interaction might improve quality learning, resulting in high academic achievement. Given the above background information, the study focused on Kenya as the study area. The study further narrowed down topics in chemistry to 'gas laws' given that the subtopic is abstract in nature and involves models and theories.

Research questions

The study was guided by four research questions as follows:

a. What is the extent to which teachers use class talk interaction during the teaching and learning of gas laws in chemistry?
b. What is the extent to which students use class talk interaction during teaching of gas laws in chemistry?
c. What is the learners' perception on use of class talk interaction during teaching of gas laws in chemistry?
d. What is the effect of teacher-learner class talk interactions on students' learning outcomes in chemistry?

Null hypothesis (H_0)

The study generated one null hypothesis: There is no statistically significant effect of teacher-learner class talk interaction on students' learning outcomes in chemistry.

Theoretical framework

The current study was guided by Constructivist Theory as propagated by Bruner (1996). According to this theory, learning involves construction of new knowledge, ideas or concepts based on learner's current or previous knowledge. The learner is able to select and transform information or data and construct hypotheses to make independent decisions. The role of the teacher is to guide the learners in translating the information learnt in an appropriate way tailored towards learners' current level of understanding. Such learning requires a curriculum organized in a spiral manner to enable learners to build upon the knowledge they already have. Teachers and learners must be actively engaged in dialogical learning. Therefore, the teacher needs to encourage learners to discover principles on their own. This theory is based on the following principles;

a. To cultivate learners' readiness to learn, the instructions must be based on learners' experiences and contexts.
b. Teaching needs to be structured in a way (spiral organization) that is easily grasped by the learners.
c. Learning should be designed to expose knowledge gaps in learners which cultivate interest and desire to fill in the gaps.

The theory was relevant to the current study because class talk interaction involves active engagement of learners and teachers in sharing learning experiences. Through class talk, learners construct new knowledge, ideas and concepts based on their current or previous knowledge. The learner is stimulated to think resulting in cognitive learning. The impact is meaningful learning outcomes. From the theoretical framework a conceptual framework was developed.

Figure 1 demonstrates how teachers and learners interact with the independent variables to yield the desired learning outcomes.

From the conceptual framework, effective use of class talk emanating from the teacher and learner form the basis of predicting the outcome which is improved learners' academic achievement. Through the independent variables, enhanced learners' engagement and inquiry-related curiosity is achieved. These help learners to be part of teaching and learning as advocated by the Constructivist Theory. Learners construct new ideas or concepts based on prior knowledge or experience. These help learners to generate their own mental models as well as making sense of their experiences. Such learning helps to resolve conflicts between ideas as well as reflecting on theoretical explanations. However, the intervening variables are likely to affect the outcomes of the learners' performance.

Methodology

This study adopted a descriptive research survey design. A target population of 10,018 Form 3 students and 298 Chemistry teachers from 118 public secondary schools in Murang'a County, Kenya, were purposively selected. The schools

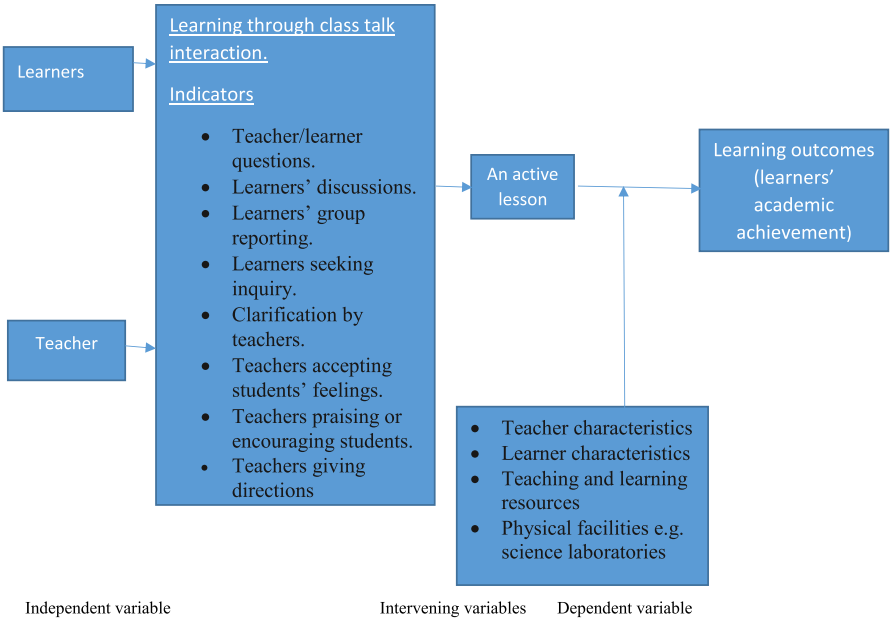

Fig. 1 Conceptual framework. *Source* Author (2020)

selected were performing averagely, with mean scores of 4.0 to 6.0, in the Kenya Certificate of Secondary Education (KCSE) examinations in the period between 2014 and 2019. The schools had not covered gas laws which was the target topic for the current study. Using Yamane's formula ($n = N/(1 + \mathrm{Ne}^2)$, (Yamane 1967), a sample size of 384 Form 3 students and 30 chemistry teachers from 30 public secondary schools were selected. Selection of the schools was carefully done to ensure equal gender representation. Regarding schools with two or more Form 3 classes, the researchers selected one class to be involved in this study through simple sampling procedure. The chemistry teacher of the selected class was also used in the study.

Each class provided 13 students as respondents (384/30 = 12.8) in the questionnaire and the Chemistry Achievement Test (CAT). To ensure a deeper understanding of the phenomenon under study, multiple data collection instruments were used thereby triangulating data collected. Feldman et al. (2013) assert that triangulation provides a more detailed and balanced situation. Four instruments were used to collect data for this study: a modified Flanders Interaction Analysis Category System (FIACS) Observation Checklist, Students' Interview Schedule, a Students' Questionnaire and a Chemistry Achievement Test (CAT). The CAT, which was out of 100, was set by three chemistry teachers who had over ten years' experience as examiners with Kenya National Examinations Council (KNEC). However, they did not participate in the actual study. To ensure high reliability and validity, items from gas laws were set from past KCSE papers sat between 2010 and 2018. A comprehensive marking scheme was also developed by the same teachers.

The four instruments were piloted in four schools that did not participate in the actual study. Pearson Moment Correlation Coefficient was used to establish the reliability coefficient of the instruments using test–retest. The CAT had a reliability coefficient of ($r=0.89$), while the Observation Schedule had a reliability measure of ($r=0.72$). The Students' Questionnaire had a reliability coefficient of ($r=0.68$). This indicates that all the instruments were reliable. To address the issues of credibility and dependability of data three research assistants with Masters in Chemistry Education degrees were recruited and trained by the lead study person on how to collect the data prior to data collection. They were also taken through the proposal so that they understood the objectives of the study. The research assistants were also taken through the process of pilot study and visited the four pilot schools in a two week period. For the purpose of uniformity, all the 30 classes in the 30 secondary schools were visited during the teaching of 'Movement of Particles' and 'Diffusion of Liquids'. A lesson plan guide was provided as shown in Table 1.

On average, gas laws topic takes ten lessons with about six subtopics to teach using teacher-learner discussion, class experiments, demonstrations and students' group reporting. For this study, 'Movement of Particles' and 'Diffusion of Liquids' were used as representative of the other subtopics. The researchers assumed that the behaviour of the teachers and learners during two lessons (80 min) of teaching 'Movement of Particles' and 'Diffusion of Liquids' would be the same in other lessons; hence, multiple observations of lessons was not done. Again, the subtopic was taught through discussion, class experiment and group reporting; thus, a cross-section of teaching methodologies were used.

On day one at the first school visited, the research assistants sat at different positions in the class during the chemistry lesson and collected observational data independently. Using one's own judgement, each research assistant assigned a numerical value 1–5 to each behaviour on the basis of strength of use portrayed by the teacher and the class during a double practical lesson. Any verbal conversation between learner-learner and teacher-learner that took place in the class, during the 80 min of instruction was considered to be class talk interaction. The research assistants were asked to be as objective as possible. Very strong behaviour was given as 5, while 4-strong behaviour, 3- moderate behaviour, 2- weak and 1- very weak behaviour. The three research assistants worked out the average final numerical value of each behaviour from the three scores. For instance, if in a given behaviour the three research assistants independently assigned, 2, 3 and 2, then the average was calculated as $\text{Average}=(2+3+2)/3=2.33$. Then 2.33 was rounded to 2.0 which was considered a weak behaviour. In Kenya, a normal class consists of 45–50 students, so, during the lesson observation, a class of 45–50 students in each sampled school was observed, where the strength of behaviour concerning the learners and teachers were recorded. The students' questionnaires were presented to the 13 respondents and they were guided on how to fill them by indicating the extent to which they agreed with the statements in the table on a scale of 1–5. The CAT was administered to the 13 respondents one week after the lesson observation.

The research assistants in discussion with the lead study person pointed out the challenges the instruments presented during the data collection process in the first pilot school. Hafen et al. (2015) noted that lesson observations during the teaching

Table 1 Lesson plan guide

Lesson duration	Sub-topic	Objectives	Activities
80 min (double lesson)	Movement of particles: diffusion of liquids	By the end of the lesson learners should be able to explain diffusion of liquids in terms of kinetic theory	a. Introduction of the subtopic with learner's involvement b. Class experiment in small groups on diffusion of liquids c. Group reporting

Source Author (2020)

and learning process are time consuming compared to teacher or student reports, but nevertheless, they offer an independent view as well as capture objective data regarding what is actually happening in the classroom environment. However, Mapplebeck (2019) asserted that observation of class talk interaction has some challenges because of the boundaries of the scale of measurements. The research assistants discussed their findings and how to score when they visited the second school. In the current study, multiple observers were used to overcome the weaknesses or intrinsic biases and the problems that arise from using a single-observer while trustworthiness of data was also enhanced. The students' questionnaire and the results of the CAT were also discussed.

The same process was repeated for the other three schools such that by the time they were finishing with the fourth school, the research assistants were conversant with the research instruments. The fourth school was visited for the second time after two weeks and the same instruments administered as a reliability test. During the pilot study, no extreme deviations were noted in the scoring of numerical values in the observational schedule from the three research assistants.

The students' interview schedule was also developed during the pilot study with the research team noting that majority of students were not asking or answering questions during the lesson. The tool developed therefore contained one question: "During the chemistry lesson, I noticed that majority of students were not comfortable with answering and asking questions, why was this so?"

The research assistants visited all the sampled schools, created rapport with the school principals, Form 3 students and the chemistry teachers, and explained the purpose of the study. Dates were set when the research assistants would visit the sampled schools. On day one, using the experience in the pilot study, the research assistants sat at different positions at the back of the class of the first sampled school and recorded the behaviour discerned as per the observation checklist. The lead study person did not inform the respondents of the behaviour that was of interest in the study. This was aimed at ensuring the data collected was a true reflection of the reality on the ground. Therefore, data collected on the behaviour of the targeted respondents was unlikely to be skewed thereby increasing the credibility and reliability of the data. Immediately after the lesson, the research assistants worked out their average Likert scale score (numerical value) from the observation schedule. Between 4.30 and 5.00 pm, each of the 13 students from the school were provided with a questionnaire and guided by the lead study person in filling it. The single question in the interview schedule was asked after the students filled the questionnaire. The same process was followed in the other sampled schools over a period of two months.

To ensure some students did not have an advantage of recent memory of the teaching over others, the CATs were administered to each group exactly one week after finishing the topic. Therefore, the CATs were administered at diverse dates depending on when each class covered the topic. The mean score of the 13 students from each class was calculated to form the dependent variable for this study. The CATs were administered during the weekend to avoid interfering with the normal school programme. Twenty eight out of the target 30 schools participated in the study which gave a return rate of 93.33% that was deemed

acceptable. According to Mugenda and Mugenda (2008), a return rate of 70% and above is acceptable as a representative of the target population. Two of the schools selected did not participate in the study because the chemistry teachers were uncooperative. SPSS Version 20 was used in coding data appropriately. Based on the study research questions, data was analysed statistically utilizing simple regression analysis and one way ANOVA. Descriptive statistics were also used to analyse quantitative data and findings presented in frequency tables, means and standard deviations. Qualitative data was analysed through sampling striking responses from learners. Triangulation of qualitative and quantitative techniques were used to achieve a valid and reliable outcome. To ensure trustworthiness of data from learners, the researcher assured them that the data collected was purely for research and would not be revealed to any other person. The researcher further created rapport with the learners to ensure they were not intimidated and guided them on how to fill the questionnaire. All the respondents of the study were provided with a consent form to fill and allowed to withdraw from the study whenever they wished to do so. Additionally, informed consent was obtained from the principals of the 30 schools involved in this study as custodians of learners who were all below 18 years of age.

Results

The results are presented as per the research questions and hypothesis.

First research question: what is the extent to which teachers use class talk interaction during the teaching and learning of gas laws in chemistry?

The 28 teachers were observed for 80 min while the research assistants recorded the class talk behaviour of interest to the study. Each observed behaviour was recorded through a Likert scale of 1–5. Numerical values were assigned to each behaviour in order to study all possible relations among the variables. Very strong behaviour was given as 5, 4 as strong behaviour, 3 as moderate behaviour, 2 as weak while 1 was very weak behaviour. Sample means for the 28 teachers from the 28 sampled schools were calculated. Results of the analysis are shown in Table 2.

The findings in Table 2 indicate the strongest teacher class talk behaviour had a sample mean of 3.3 which reveals that teachers were using more of the lecture method to teach than other methods of teaching. This was closely followed by a sample mean of 3.2 on asking questions which implies that teachers were moderate in teaching through the question method. Praising or encouraging students had the least sample mean (2.4), implying that teachers were weak in praising and encouraging learners. Accepting the students' feelings had a sample mean of 2.7 which is average behaviour. Giving direction, which included clarifications and guidance, scored 3.1 which was above average.

Table 2 Sample mean, standard deviation, standard error of mean teachers' class talk behaviour scores ($N=28$)

Teacher class talk behaviour while	Sample mean	SD	SEm	Min	Max
Accepting students' feelings	2.7	0.7	0.1	1	4
Praising or encouraging students	2.4	0.7	0.1	1	4
Asking questions	3.2	0.8	0.2	1	4
Lecturing	3.3	0.8	0.2	2	5
Giving direction	3.1	0.9	0.2	1	5

Source Modified from Flanders interaction analysis category system (FIACS)

Second research question: what is the extent to which students use class talk interaction during teaching of gas laws in chemistry?

Giving reports, responding, asking questions, enquiring or seeking clarifications, discussions, peer teaching and silence were used to rate students' class talk behaviour during the teaching and learning of gas laws in chemistry. Through observation of the learners, the research assistants rated the behaviour of interest using a Likert scale of 1–5 in each of the 28 classes from the 28 sampled schools. Numeric values were assigned to each response in order to study all possible relations among variables. A very strong behaviour was rated 5 while 4 was rated as a strong behaviour, moderate behaviour was rated 3, 2-weak behaviour while 1 was very weak behaviour. The percentage of classes rated under each numeric value (1–5) was calculated. Table 3 shows the percentages of classes whose students exhibited each verbal behaviour under investigation.

From Table 3, on giving reports of their discussions or experimental results, the findings reveal that 50.0% had students who were very weak while 21.4% were weak. On response to teachers' questions, 35.7% had students who were weak while

Table 3 Percentage of classes whose students exhibited each verbal behaviour during teaching and learning of gas laws ($N=28$)

Class verbal behaviour	Class frequency in percentage				
	1	2	3	4	5
Give reports	50.0	21.4	17.9	10.7	0.0
Response to teacher's questions	0.0	35.7	32.1	28.6	3.6
Ask a question	82.1	7.1	7.1	3.6	0.0
Enquire or seek clarification	89.3	7.1	3.6	0.0	0.0
Discussions	78.6	3.6	7.1	7.1	3.6
Peer teaching	46.4	35.7	10.7	7.1	0.0
Silence	10.7	21.4	10.7	14.3	42.9
Overall average	51.0	18.9	12.7	10.2	7.2

Source Modified from Flanders interaction analysis category system (FIACS)

5 = Very strong behaviour, 4 = Strong, 3 = Moderate, 2 = Weak and 1 = Very Weak

32.1% were moderate. The findings indicated that there were no extreme cases of very weak but an insignificant percentage (3.6%) of very strong cases regarding learners' responses to teachers' questions was noted. However, 28.6% of classes indicated a strong behaviour and 3.6% indicated very strong behaviour, giving a total of 32.2% of those who can be interpreted to have responded comfortably to teachers' questions. Therefore, majority of classes (67.8%) had students who can be considered poor in responding to teachers' questions. Regarding asking of questions, majority of classes (82.1%) had students who were very weak in asking questions. On enquiring or seeking clarification, majority of classes (89.3%) had students who were very weak which means that passive learning dominated the learning process and indeed, the use of discussions was rated as very weak with 78.6% of classes.

On peer teaching, 46.4% and 35.7% of classes had students who were very weak and weak respectively implying either lack of confidence or lack of teacher training in peer teaching. With regard to silence, 42.9% of classes portrayed students with very strong behaviour, while 14.3% indicated strong behaviour. This means that 57.2% of classes had students who were silent throughout the lesson, which should be a matter of concern to chemistry teachers. Overall results in percentage revealed that majority (51%) of classes had students very weak in class talk interaction.

Third research question: what is the learners' perception on use of class talk interaction during teaching of gas laws in chemistry?

To answer this question, each learner was provided with a questionnaire. On a scale of 1–5, they were instructed to indicate the extent to which they agreed with the statement as indicated in the table below, where 5-strongly agree, 4-agree, 3-not sure, 2-disagree, 1-strongly disagree. Table 4 indicates the frequency of responses of the respondents in percentages.

The findings from Table 4 revealed that 18.2% and 20.1% of learners strongly agreed and agreed respectively on enjoying asking questions. This is a total of 38.3% of learners, while 19.2% and 31.2% strongly disagreed and disagreed respectively, giving a total of 50.4% who do not enjoy asking questions. Therefore, majority of learners do not enjoy asking questions during the chemistry lessons. The second statement had similar responses; majority of learners (48.7%) disliked answering questions. This is supported by the low means in the first (2.5) and second (2.2) statements. Asked why they disliked asking or answering questions, the researcher sampled some striking responses as, reported verbatim and findings presented in Table 5.

Regarding the third statement, majority of learners (71.6%) strongly agreed and 21.1% agreed that their chemistry teachers encouraged them to ask questions as well as seeking clarifications. On the fourth and fifth statements, majority of learners agreed that they understand chemistry more during discussions with either the teachers or classmates. Majority of learners admitted understanding chemistry during discussions with teachers (81.6%) and amongst themselves (84.0%). From the summary of the results, 39.5% of learners strongly agreed and 28.9% agreed that

Table 4 Learner's perceptions on learner-teacher class talk interactions ($N=384$)

	Statement	Learner's frequency in percentage						
		1	2	3	4	5	Mean	Std. dev
1	I enjoy asking questions during the chemistry lessons	19.2	31.2	11.3	20.1	18.2	2.5	1.2
2	I enjoy answering questions during the chemistry lessons	7.7	41.0	5.9	37.9	7.5	2.2	1.0
3	Our chemistry teacher encourages us to participate actively in class through talking, asking questions and seeking clarifications	1.9	3.5	1.9	21.1	71.6	4.6	0.9
4	I understand chemistry more during discussion with my classmate	2.7	4.5	8.8	28.7	55.3	4.1	2.1
5	I understand chemistry more during discussion with the teacher	9.3	6.1	3.0	36.7	44.9	4.2	1.2
	Overall average	8.2	17.3	6.2	28.9	39.5	3.5	1.3

Source Researcher (2019)

Table 5 Sampled learners' striking responses on why they disliked asking or answering questions

School	Response
A learner in School 1	"Because I do not understand chemistry"
A student in School 7	"I fear being laughed at"
A student in School 10	"For fear of making mistakes"
A student in School 12	"I am just shy"
A student in School 17	"I answer when asked directly"
A student in School 28	"No good reason"

class talk interaction was practiced during the teaching and learning process in the sampled classes.

Fourth research question: what is the effect of teacher-learner class talk interactions on students' learning outcomes in chemistry?

To answer this question, data was subjected to simple regression analysis and results are indicated in Table 6.

Table 6 indicates the standardized coefficients (Beta) as 0.614 meaning that when class talk interaction is increased by a single unit, the resultant effect is an increase of the dependent variable (learners' mean score) by 0.614 units. In this study, the R^2 referred to as the statistic coefficient = 0.377, indicates the ratio of variation that the independent variable accounts for. The implication is that 37.7% of academic achievement was accounted for by class talk interaction which was the independent variable in the study. Therefore, from the simple regression analysis, during the teaching and learning of gas laws in chemistry, class talk interaction contributed

Table 6 Effect of combined teacher-learner and learner-learner class talk interaction on learners' academic achievement in gas laws in Chemistry ($N = 28$)

Model summary				
Model	R	R^2	Adj. R^2	Std. Error
1	0.614	0.377	0.301	10.180

Coefficients					
Model	Unstandardized coefficients		Standardized coefficients	T	Sig
	Beta	Std. Error	Beta		
(Constant)	−9.987	14.178		−.704	0.525[a]
Verbal	19.874	3.998	0.614	4.971	< 0.001

Source Researcher (2019)

Dependent variable: learning outcomes (student mean score)

[a]Predictor: (Constant), Class talk interaction

37.7% of the dependent variable, implying that other variables that were not part of the model contributed 62.3% of the dependent variable.

The equation model was: $Y = -9.987 + 0.614X$, (Y is mean score value for the 13 student participants from each school in the study, X is the combined teacher-learner and learner-learner class talk interaction, -9.987 is the constant while 0.614 is the slope or standardized coefficient). Results arising from this study indicate that teacher-learner class talk interaction was a predictor of students' learning outcomes in gas laws in chemistry.

Hypothesis (H_0) testing

The study tested one null hypothesis:

There is no statistically significant effect of class talk interaction on students' learning outcomes in chemistry.

From Table 7, the one way ANOVA results indicate that the F calculated value (F_{cal}) = 15.64 is greater than the critical F value in the table (F_{tab}) = 4.20 at the desired level of 0.05 confidence level and at one degree of freedom, 1df (1, 28). When the $F_{cal} \geq F_{tab}$ for the appropriate degrees of freedom is analysed, the findings are considered statistically significant at the chosen probability (α) level (Best and Kahn 2011). Therefore, the one way ANOVA analysis indicated that the null hypothesis was rejected. Hence, the findings of this study revealed a statistically significant effect of teacher-learner class talk interaction on students' learning outcomes on gas laws in chemistry in public secondary schools in Murang'a County, Kenya.

Discussions

The first study objective was to observe teachers and rate them on the use of several class talk practices. The findings indicated that teaching through lecture method had the highest sample mean of 3.3 compared to other teacher class talk behaviour. The interpretation here is that passive learning was still dominant in Kenya during instructional practice. This is against the best practice in teaching and learning. Learners should not be considered empty vessels that attend class only to be fed with knowledge where teachers are assumed to be the only source of knowledge. In supporting this argument, Paulo Freire, in the late 1950s and 1960s asserted that

Table 7 Hypothesis testing on statistically significant effect of class talk interaction on students' learning outcomes in gas laws in chemistry ($N = 28$)

ANOVA						
Model	Model	Sum of squares	Df	Mean square	F_{cal}	F_{tab}
1	Regression	1869.298	1	2011.574	15.64	4.20
	Residual	3473.663	27	128.654		
	Total	5342.961	28			

learners are not objects; rather, they are subjects during the learning process and should determine their destiny (Cole 2009). This means that learners should be trained and encouraged to build on what they know to generate new knowledge. Therefore, sharing of knowledge through class talk interaction is a fundamental factor to meaningful learning.

Apparently, in Kenya, every chemistry teacher employed as a teacher after preservice training undergoes a teacher's professional development course through the Strengthening of Mathematics and Science in Secondary Education (SMASSE) inservice training (Wafubwa 2014). SMASSE is a programme which was initiated by the Kenya Government in collaboration with the government of Japan to offer inservice training programs to science and mathematics teachers on the best teaching approaches and methodologies. Through SMASSE, teachers are discouraged from using passive learning. The findings of the current study reveals that SMASSE inservice is yet to achieve its objectives despite the government's heavy investment in the program.

Praising or encouraging students had the lowest sample mean (2.4) which implies that teachers were weak in praising and encouraging learners. Everyone feels motivated when praised and encouraged. Learners are not the exception to this and the desire to learn increases when they are praised and encouraged by the teacher. This argument is supported by several studies: Brophy and Evertson (1981) asserted that students' academic achievement and the frequency of praise and encouragement are highly and positively correlated while studies by Kebwaro (2016) and Paul et al. (2020) revealed that teachers' praise and positive attitude towards learning are statistically significant. Therefore, lack of praise and encouragement played a significant role in inhibiting quality learning and leads to low academic achievement.

Accepting the students' feelings delineated a sample mean of 2.7, which is moderate behaviour. Teachers who are good at accepting the feelings of the students reduce the mental distance between the students and themselves while students are attracted to their subjects which leads to meaningful learning that is likely to lead to quality learning outcomes. This is supported by Mahmoodi (2016) who asserted that kind behaviour and acceptance of students' feelings by the teacher increases the learners' desire to learn and improves quality teaching and learning with a resultant improvement in learning outcomes. Teachers who accept the feelings of the learners are likely to have a positive attitude towards the learners' ability; a factor that is likely to attract learners to enjoy their subjects whose result is high academic achievement. Therefore teachers' moderate behaviour in accepting students' feelings may have contributed to students' dislike of chemistry, hence poor performance. The finding are consistent with findings of a study by Musyoki (2015) which established that one cause of students' poor performance in Chemistry in Machakos County, Kenya, was teachers' negative attitude towards their learners' ability.

Regarding teachers asking questions, the sample mean of 3.2 indicated a moderate behaviour. Questions help a teacher to get feedback from learners enabling him or her to assess the achievement of the lesson objectives. Giving direction, which included clarifications and guidance, had a sample mean of 3.1 which can be rated as a moderate behaviour which should be improved. This is because giving direction during the teaching process is important as it gives learners confidence in what

they are doing during the teaching and learning process. The findings of the current study reveal that teachers in Kenya were practicing class talk interaction at a moderate level. This is likely to hinder effective learning and renders chemistry unpopular.

The second study objective was to observe learners and rate their use of various class talk practices. The current study observed that students were weak in all the investigated verbal behaviour except response to teachers' questions (35.7%) and silence (32.1%). One concern about the findings of the current study is that 89.2% of learners were weak in asking of questions while 96.4% were weak in seeking clarifications. The high percentages suggest that either learning did not take place and thus students could not ask questions or they understood the content. However, in chemistry, meaningful learning is unlikely to take place during a lesson when the learners do not ask questions or seek clarifications. This is a critical factor because it is through questions and answers that a teacher is able to evaluate the lesson and identify gaps in the teaching methodology used. However, the results suggest that of all the verbal behaviour investigated, students responding to questions represent the strongest positive behaviour (64.3%), excluding silence. It was not clear why learners were weak in asking questions and seeking clarification while they were moderate in responding to teachers' question. This seems to contradict the two behaviours thereby creating a gap that requires further investigation.

Majority of students (67.9%) were silent throughout the lesson—an issue that should provoke the chemistry teachers to find out why. However, this aspect of silence conforms with the findings of a study by Frymier and Houser (2016) on the role of class talk participation in student engagement which noted that approximately 70.0% of student respondents were silent. Frymier and Houser's study revealed that sociocultural backgrounds, learning preference, motivation and preparation are some reasons for the silent behaviour. Findings of the current study revealed that understanding the content, lack of fear of being laughed at, fear of making mistakes and shyness are the most probable causes of the silence that are likely caused by cultural influence. Similar findings from studies by Mbugua et al. (2012) and Ogembo et al. (2015) cited cultural factors as a cause of low achievement level in mathematics and chemistry subjects among students in Kenya.

Dufresne, et al (1996) asserted that class talk improves students' attitudes and motivation toward science. It is the opinion of the researcher that the identified possible causes of silence in the current study can be skilfully addressed using appropriate class talk interaction in a social context. Such a pedagogical technique is likely to improve students' attitudes and motivation toward chemistry. The current study was done using rural students from one ethnic community. It is important to do a similar study in a cosmopolitan setting where students are unlikely to be shy and fearful to teachers and one another.

The fact that majority of students (96.4%) were weak in inquiring or seeking clarification, (71.4%) were weak in giving reports of their discussions or experimental results, and 82.2% were weak in discussions suggesting that passive learning dominated the learning process. Passive learning was confirmed by results of the first research question where it was found that the lecture method had the highest sample mean. The interpretation is that learners were very weak in sharing the results of their group discussions and experiments through class talk which is fundamental to

meaningful learning in a social context. Annapurna and Massarat (2018) and Pollock, Harmann and Wilson (2011) asserted that when learners are involved in giving reports during discussions, they gain confidence, raise the desire to learn and discourage passive learning resulting in a high academic achievement. Majority of learners (82.1%) were weak in peer teaching, viewed as another indicator of the poor situation in the classroom in regards to learner-learner class talk, resulting in poor quality learning. This is because learners are expected to be free with one another, seeking clarifications and learning from one another; a phenomenon that should be encouraged in a learning setting. As advocated by Constructivist theorists, learners' class talk participation plays a significant part in facilitating learners to internalize the concepts in a lesson. As learners generate knowledge through class talk, they become part of the learning environment and own what is learnt. In such circumstances, they can easily recall what they learnt. This in turn helps the learner to gain confidence, encouraging learners to not only seek knowledge but also to enjoy learning and build new knowledge from the existing one. The overall students' class talk interaction during the chemistry lessons indicated that 51.0% of students were very weak in class talk which a factor that is likely to make learners dislike the subject. This is consistent with findings from studies by Khaombi (2016), Makato (2016) and Yunus and Ali (2012), which established that majority of students in Kenya dislike the subject.

The implication of the findings of the current study is that learners constructed very little knowledge due to their weak class talk behaviour. This weakness was therefore identified by this study as one of the factors that contributes to poor academic performance in chemistry in Kenya. In the United Kingdom, for instance, one policy is that teachers should provide learners with frequent feedback through class talk interaction and accurate marking (Mapplebeck and Dunlop 2019). In addition Azmi and Sham (2018), note that teachers need to improve the learning environment through a relaxed, low-stress environment and enhance learners' self-assurance through class talk interactive lessons. The current study is convinced that better learning outcomes can be realized if more class talk interaction is practiced by chemistry teachers.

The third study objective was answered through administering a questionnaire to learners. From the findings, majority of learners (50.4%) did not enjoy asking questions and a further 48.7% disliked answering questions. Though a slight difference, this conforms to the findings in the second study objective where 35.7% of students were weak in responding to teachers' questions while majority (89.2%) were weak in asking questions. As pointed out earlier, this could be either due to learning not taking place and thus students could not ask questions or they understood the whole content which is unlikely, or due to cultural influence.

However, while learners indicated that chemistry teachers encourage them to share their experiences, ask questions and respond to the teachers' questions, the learners, interestingly, were found to be very poor in sharing experiences, asking questions and responding to questions. This can be interpreted to mean that learners' attitude towards chemistry subject needs to be improved by the teachers. Teachers have the capacity to change learners' attitude by employing tactful means like class talk interaction. However, it is the opinion of the researcher that teachers were keener

on finishing the syllabus rather than ensuring that they engage learners through class talk. Students' verbatim reports in the current study confirmed that the students have a negative attitude towards Chemistry which is consistent with previous studies by Khaombi (2016), Makato (2016) and Musyoki (2015), Ngila and Makewa (2014) that were conducted in Kenya. However, teachers are agents of change and are expected to inculcate positive values to learners. As such it is the opinion of the researcher that encouragement, patience and attention from the teacher through class talk interaction may change the learners' negative attitude towards chemistry. The overall 39.5% of learners who strongly agreed and 28.9% who agreed that class talk interaction was practiced during the teaching and learning process in the sampled schools was an indicator of active lessons during instructions.

Results arising from the fourth research question indicated that teacher-learner class talk interaction was a strong predictor of students' learning outcomes in gas laws in chemistry. This is because class talk interaction alone contributed 37.7% of the dependent variable while 62.3% was sum contribution of many other variables including teachers' and students' characteristics, learning resources and learning environment. The findings were consistent with findings of hypothesis testing which revealed a statistically significant effect of teacher-learner class talk interaction on students' learning outcomes. The implication of the statistical testing is that when the teachers and learners use class talk interaction during the teaching and learning process, quality learning is improved with a resultant enhancement of learning outcomes as measured in the academic achievement of the learners. Research question four and the null hypothesis findings of the current study conform with findings of a similar study conducted by Cheruiyot (2015) in Baringo sub-county, Kenya, that established a positive correlation between class talk interaction and students' academic achievement in physics. Mahmud (2014) study on the influence of class talk interaction on academic success revealed that class talk interaction significantly and positively influenced academic achievement of learners, albeit the study used a small sample size. What emerges from the current study is that class talk needs to be included in the lesson plan and skilfully utilized by teachers and learners. This is likely to enhance learners' engagement and inquiry-related curiosity. Such a lesson would not only be interesting to learners, but it also would result in better achievement of the lesson objectives. Therefore, class talk interaction learning leads to high motivation which encourage learners towards learning activities. This strengthens the learners' understanding due to enhanced interacting skills. From the findings, chemistry teachers can improve the academic performance and popularize the subject if they can supplement other common teaching methods with class talk pedagogical practices. Provision of trained, competent and effective teachers is a vital aspect to improve achievement in chemistry (Hassan 2015). As such, findings from the current study suggest that teachers' effectiveness and competencies can be improved through use of class talk interaction.

Luu and Nguyen (2010) assert that when learners are involved in class talk interaction, for instance during discussions, negotiations, joint problem solving tasks and dialogue, their mastery of the subject increases. Such a learning environment helps learners to be creative, innovative and share experiences, and further, the learners become creators of knowledge. As creators of knowledge, the learners are better

prepared with higher cognitive skills that enable them to solve societal problems. This is supported by Wuhyuni (2018) who asserted that teachers with an understanding of the importance of class talk interaction become effective and creators of meaningful learning. However, the findings of a related study by Ali and Mahfoodh (2019) differed with the results of the current study; establishing a strong negative correlation between academic class talk interaction and learners' prior learning experience. Findings of a study by Frymier and Houser (2016) differed with the long held perception that class talk interaction is unquestionably an effective method of teaching and rather argued that teachers should reassess their grading method of class talk interaction. This study therefore suggest that, to implement class talk interaction requires teachers with a positive attitude towards learners.

Conclusion

Although there are many factors that contribute towards quality learning, the empirical findings of the current study revealed that class talk interaction is a strong predictor of learning outcomes. Further, the study indicated that in the study area, learners were very weak in the use of class talk interaction, an aspect that requires to be addressed. Learners were found to have a poor attitude towards chemistry subject. Indeed, one could for example ask why a teacher would not care when half the class is silent. The study further established that passive learning was most dominant despite teachers' awareness about its weakness as an instructional method. The thesis of the study based on Constructivist Theory was that lack of adequate class talk interaction in the class room environment was identified as a major factor contributing to unpopularity of chemistry and poor performance. A teacher's ability to create a conducive class talk interactive environment is a means towards achievement of desired learning outcomes. Therefore, teachers should be in the forefront of delivering active class talk interactive lessons. Finally, use of class talk interactions may popularize chemistry subject and address the academic performance gaps.

Contributions to the existing body of knowledge

Due to a variety of variables in class talk interaction, teachers can derive almost immediate feedback about the lesson. The results of the current study support policy efforts to improve student academic achievement by promoting class talk interaction during instruction. The study highlights areas where teaching practice can be improved. Students will become aware of their skills gaps and the discovery that they are also sources of knowledge may prepare them to be better scientists. Teachers will utilize the class talk interaction skills to create interest during the chemistry lessons and to attract more students to take the subject. Class talk interaction will not only reinforce the existing familiar teaching methods, but further, can be tried in other subjects in the secondary school curriculum. The implication of this adoption is a reviewed and renewed teaching approach in the secondary school curriculum. From that perspective then, class talk can be considered a mandatory education

practice since it could provide future opportunities for quality learning. Finally, due to the fact that the researcher may not generalize the conclusions arising from the study, a contribution of new body of knowledge was made which can be used to generate research questions to further research on class talk interaction.

Recommendations

The Ministry of Education should plan for teachers' professional development workshops and in-service courses that emphasize class talk interactions. The study recommends further studies with use of different subjects, level of learners and learners from different cultural background for comparative results so that the results of the study can be broadly generalized.

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Data availability I confirm that data will be available on request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in the study involving human respondents were in accordance with the ethical standards of the National Commission for Science, Technology and Innovation (NACOSTI), Kenya, and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all respondents included in the study. Additional informed consent was obtained from the principals from school where students were involved in this study.

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