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Effect of Computer Aided Instruction on Students' Academic and Gender Achievement in Chemistry among Selected Secondary School Students in Kenya

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Abstract
The role of computers in classroom instruction is gaining prominence in developing countries especially in Kenya for Science subjects, in particular Chemistry subject whose performance has been low. This paper presents a section of a study in Kenya which investigated the effect of Computer Aided Instruction (CAI) on students' achievement in Chemistry as compared with Conventional Instructional Methods (CIM). This study was prompted by the emergence of IT resources mainly in courtesy of the government and some non-governmental organization (NGO). The study targeted 15 secondary schools with computer laboratory in Tharaka Nithi County, Kenya. A total comprising of 174 Form Two Chemistry students from Four secondary schools with computer laboratory were purposively sampled. The four schools were randomly assigned to either Experimental or Control groups. The Experimental groups were taught with CAI while Control groups were taught with CIM (Conventional Instructional Methods) on the topics "Atomic structure, Periodic Table and Chemical families" for six weeks. Data was collected using Chemistry Achievement Test (CAT). The CAT was administered before and after treatment (CAI) to both Experimental and Control groups. The content validity of the CAT was checked for by a panel of secondary school Chemistry teachers who were not from the schools under study. The researcher administered the CAT instrument (pre-test and post-test) with the assistance of Chemistry teachers in the sampled schools. Data was analyzed using both descriptive and inferential statistics. The differences between the group means was analyzed using t-test, Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA). The statistical significance was tested at $\alpha = 0.05$. The study posted a significant difference in academic achievement in Chemistry between the CAI and CIM groups, with students of CAI group obtaining higher Chemistry scores than students of CIM group. The study further revealed a significant gender difference in Chemistry academic achievement in fovour of girls. Based on these findings, it was therefore recommended that Chemistry teachers should adopt use of CAI in their teaching for improvement of students' academic achievement in Chemistry and in particular, the girls.
Keywords: Computer aided instruction, Conventional instructional methods, Academic achievement, Gender and Chemistry.

1. Introduction

Computer Aided Instruction (CAI) is an instructional technique based on the principle of programmed instruction and makes use of a combination of tutorial, computer simulation activities and drill and practice programs (Stennet, 1985). CAI is a very powerful instructional technique for classroom instruction as it provides an interaction between an individual learner and the computer, and is able to display the instructional material just as it happens in the tutorial system between the teacher and the individual learner (Olagunju, 2013). In addition, CAI facilitates the learning by providing individualized instruction, effective interaction with the learner and immediate feedback (Tyagi, 2014). More importantly, it can support learners both cognitively and affectively. Cognitively, CAI focuses on learners' attention on information relevant to learning or task at hand (Jarvela, 1995), reduce learners' cognitive load (Oliver, 1999) and prevent them from feeling frustrated by difficult tasks (Rosenshine & Meister, 1992).

Affectively, CAI offers students emotional support through engaged environments which can lead to successful learning, hence they gain confidence or attach positive feeling to learning (Driscoll, 2000). For this reason, use of CAI in schools is increasing tremendously all over the world.

1.1 Academic Achievement in Chemistry

The low academic achievement in Chemistry education exists in countries across the world. In USA, science performance of majority of US students has been below average. For instance, a report by National Assessment of Educational progress, NAEP, (2015), a project of the federal education department, observed that only 29% of Americans country's K-12 education in science, technology, engineering and mathematics (STEM) were rated as above in the world and that 40% of 12^{th} –graders were rated below basic in science. In Europe, a report by the European Commission (2010), indicated that more than 20% of young European students were not reaching a minimum level of basic skills in numeracy and literacy in mathematics and science. In addition, European Commission (2010) report indicated that students' performance in science in several European countries was

lower than the European Union (EU) average (501.3), on a score scale between 400 and 600 points. However, the EACEA/Eurydice (2011) report indicated that the gender differences in science achievement were insignificant. Although in the European countries the gender gap in science achievement appeared small overall, gender differences in science were substantial within schools or programmes (EACEA/Eurydice, 2010). In Kenyan context, students' performance in Chemistry has been low as witnessed in other countries discussed above (KNEC, 2007-2015). This situation is illustrated in Table 1 of the students' performance in Chemistry in percentage at the KCSE examinations.

Table 1: Students' Performance in Chemistry at KCSE: 2009 to 2015 in (%) at National Level

Year	No. of candidates	Overall- Mean scores	Boys-Mean scores	Girls- Mean scores
2009	328922	19.13	20.43	17.56
2010	347378	24.91	26.62	22.80
2011	403107	23.66	25.42	21.47
2012	427303	27.93	29.54	25.95
2013	439847	24.83	26.30	23.08
2014	476582	32.16	33.88	30.18
2015	515888	34.36	35.86	32.64

Source: KNEC Reports (2009 to 2015)

Table 1 indicates average scores in Chemistry at KCSE in the years 2009 to 2015. These mean scores are equivalent to grade D- to D+, which are far below the expected grade C+, a requirement to qualify for courses that are Science related at the Kenyan university. Implying that majority of the secondary students in Kenya do not qualify to undertake any science oriented course at university. This is an issue that ought to raise genuine concern. On the same analysis, the results indicates that the performance of girls is poorer than that of boys. Gender difference in science achievement, including Chemistry exists in countries across the world. For instance, Martin, Mullis and Chrostowki (2004) observed that boys worldwide showed significantly greater achievement in science. In United States, female students' average scores were lower than those of male students in science tests at secondary and post-secondary level (Lorenzo, Crouch & Mazur, 2006). Additionally, Eshiwani (1982) and FAWE (1999) made similar observation that science achievement, Chemistry included, for girls is lower than that of boys. This under achievement of girls than boys in Chemistry is a matter of great concern.

1.2 Purpose of the study

This article reports on research conducted to investigate the effect of Computer Aided Instruction on students' academic and gender achievement in Chemistry in secondary schools in Kenya. This entailed comparing the outcomes in the CAI and Conventional Instructional Methods (CIM).

It is important to determine the effect of Computer Aided Instruction on students' academic and gender achievement in Chemistry as compared with conventional instructional methods. More so, it is necessary to find out whether use of CAI would have helped in addressing the persistent low academic and gender achievement witnessed in Chemistry among Kenyan secondary school students.

1.3 Hypotheses

The study was guided by the following hypotheses and tested at 0.05 level of significance

$H_0$1: There is no significant difference in students' academic achievement scores in Chemistry between those taught using CAI and those taught using CIM.

$H_0$2: There is no significant gender difference in Chemistry achievement scores when both boys and girls are taught using CAI.

2. Literature review

Computer Aided Instruction (CAI) has been used over decades for educational purposes and as a method for addressing improvement in students' learning outcomes. As Fraser, Walberg, Welch and Hattie (1987) observed, use of CAI for instruction resulted in increased student interest, cooperation and achievement in science. Similarly Serin (2011) found that fourth year students in the science and technology in Turkey who received computer aided instruction obtained a higher achievement than those who were exposed to traditional method. Kareem (2015) also observed that improvement in students' academic achievement in Biology resulted from use of CAI. Several studies on CAI affirm to its positive impact on students' academic achievement (Olga, 2008; Serin, 2011; Ahiatrogah, Madjoub & Bervell, 2013; Jesse, Twoli & Maundu, 2014; Nduati, 2015; Kareem, 2015).

According to Bhagwan (2005), CAI brings several possible advantages as a teaching/learning tool over the conventional methods. These advantages of CAI in teaching and learning include; promote positive effect on student's attitude, makes instruction more student-centered, shift the teaching and learning from teacher-centered to a student- centered environment, encourages collaborative learning and stimulates increased teacher-student interaction, promote active learning and provides evaluative learning. Lawson (1999) points that a student while

using CAI may review particular topics on which he/she needs clarification and if familiar with the topic, may quickly progress at a faster rate to other topics. This is in contrast to conventional methods, in which learning is based on a predetermined time, where students are expected to master the topic during that time. The CAI can therefore enable self-paced learning in which learners can proceed at their own pace, unlike for conventional instructional methods. Mauro (1994) echoes that CAI provides self-directed learning to students and allows the learners to become empowered to more responsibility to choose, control and evaluate their own learning activities which can be pursued at any time and in any place. These advantages of CAI makes the learning of Chemistry more effective than the conventional methods.

2.1 Conceptual Framework

The study was based on constructivism theory, which view learning as an active process of knowledge construction by learners. CAI is linked to constructivist theory in that students in CAI classrooms are at the center of the learning process and that are actively involved in constructing knowledge rather than being passive recipients of instruction. The study hypothesized that for improved students learning outcomes to be realized, the instructional methods used by the teachers have to succeed positively in enhancing learning of chemistry. In Chemistry teaching, the instructional methods play a major role in determining the students' success in learning outcomes. Research indicate that the content delivered in a computer based instruction is more effective than that presented in conventional classrooms (Abdous & Yoshimura, 2010). In this study, Chemistry instructional methods were categorized in two major main groups that is, the Conventional Instructional Methods (CTM) and Computer Aided Instruction (CAI). The independent variables for this study were the Computer Aided Instruction (CAI) and Conventional Instructional Methods (CIM) while the dependent variables were students' academic achievement while the intervening variables include; teachers experience and training, and gender of the students. The experience and training that the teacher has, determines how effectively the teacher will use the teaching approach. Some researchers agree that teaching experience during the first few years of teaching is positively correlated with students' achievement (Kosgei, Mise, Odere & Ayugi, 2013). Gender was inbuilt in this study in order to statistically control for its variation (Fraenkel & Wallen, 2000).

The interactions among the independent variables, intervening variables and dependent variables that were used for the study are diagrammatically represented as shown in Figure 1

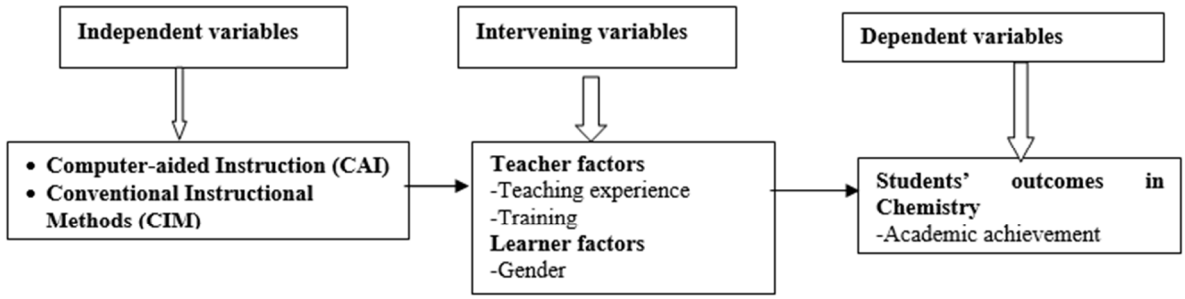

Figure 1: Conceptual Framework for the use of CAI and CIM in learning Chemistry

3. Research Methodology

The study was carried out in Tharaka Nithi County which is in Kenya. The County was deemed appropriate for the study because the students' performance in Chemistry has remained low over many years. For instance, analysis of KCSE data in the years 2009 to 2015 reveals an average achievement mean score of 26.52% to 39.42% at the sub-county level and mean score of 19.13% to 34.36% at the national level.

3.1. Research design

The study adopted Quasi-Experimental design based on Solomon Four-Group, Non-equivalent Control Group. Quasi-experimental design involves no randomization of the subjects to the sample groups but rather involves random assignment of intact classes to sample groups (Borg & Gall, 1989). The Solomon-Four group design is illustrated in figure 2.

	Pre-test	Treatment	Post-test
Group E1(boys)	O_1	X	O_2
Group C1(girls)	O_3	X	O_4
Group E2(girls)		X	O_5
Group C2(boys)		X	O_6

Figure 2: **Solomon-Four Group, Non-equivalent control group design**

As indicated in Figure 2, the notations are: EI= Experimental group 1, C1= control group 1, E2= Experimental group 2, C2= Control group 2, O_2, O_4, O_5, O_6= Post-test, O_1, O_3= Pre-test, X= Treatment (computer aided instruction), (X) = No treatment (conventional methods).

3.2 Participants and Sampling Procedures

The participants in this study were 174 Form Two Chemistry students from four secondary schools with computer laboratory. The participants were in four intact groups. Group EI included 45 boys; Group E2 comprised of 46 girls; Group C1 consisted of 45 girls and Group C2 comprised of 38 boys. The Form Two students were preferred to other levels (forms) for the study because at this level, study of Chemistry is compulsory and the students were acquainted with computer skills. Four secondary schools were purposively sampled from the 15 secondary schools with computer laboratory in Tharaka Nithi County, Kenya.

Purposive sampling was used in order to select schools with similar academic level as possible because the research was a comparative study. Since computer laboratory was a key resource that was required for CAI lessons, only schools with such facilities were sampled. The assignment of the four schools (groups) to either experimental or control conditions was done using simple random sampling. Random sampling gives each and every school from the target population a known and equal probability of selection (Kothari, 2004). In case, the school had more than one stream, only one stream was randomly sampled for the study.

3.4 Research Instrument

Chemistry achievement test (CAT) was used to collect data on students' academic achievement in Chemistry. Two assessment tests were used; the pre-test and post-test. The pre-test achievement test was used to measure the students' achievement in chemistry before the exposure of the treatment (CAI). The post-test was used to measure the students' achievement in Chemistry after the treatment. The pre and post-achievement tests were constructed by a panel of qualified and experienced teachers and under the supervision of two specialists each in Chemistry education and measurement and evaluation. Both pre-test and post-test chemistry achievement tests contained either short-answer questions or structured questions with different scores in each question and total score of 40 marks. The questions for the pre-test were based on the topic "Matter and its constituents" in Form One chemistry syllabus while those of post-test were based on the topic "Structure of an Atom, Periodic Table and Chemical Families" in Form Two Chemistry syllabus.

3.5 Data Collection procedure

The CAI software was first installed in the computers of the Experimental schools. Chemistry teachers of these schools were trained on how to use Computer Aided Instruction (CAI) for one week. The CAT-pre-test was administered to the students of the Experimental group 1 and Control group 1 before the exposure of the treatment. This pre-treatment period was designed to last for one week. The pre-treatment period was followed by exposure of treatment to the Experimental groups that were taught the topics "structure of an atom, periodic table and chemical families" using CAI for a period of six weeks. Similarly, students in the control groups were taught the same selected topics for the same period of time using CIM. At the end of treatment period, the regular teachers administered the CAT post-test to the students in both Experimental and Control groups.

3.6 Data analysis

After the administration of Chemistry post-test to the four groups, the test for each and every student in the four groups was marked and scored out of 40 marks. The quantitative data was then put into spreadsheet into four different categories and analyzed as per group using both descriptive and inferential statistics using SPSS. The descriptive statistics included computing means and standard deviations. The descriptive statistics were used to describe the data. The t-tests, Analysis of Variance (ANOVA) and Analysis of Covariate (ANCOVA) were run to determine the statistical significance and difference between the group means. The ANCOVA test was performed using KCPE science marks as the covariate in order to cater for the initial difference among the groups, while the ANOVA test was performed to determine the difference in the means of the four groups and independent samples t-test was performed to determine the differences in the means of two groups (boys and

girls). This is because t-test has the power to detect differences between two means (Borg & Gall, 1989).The statistical significance of the hypothesis was tested at $\alpha = 0.05$. The data analyzed was finally presented in tabular form.

4. Results and Discussion

The results of the study were based on the following hypotheses;

i) There is no significant difference in students' academic achievement scores in Chemistry between those taught using CAI and those taught using CIM.

ii) There is no significant gender difference in Chemistry achievement scores when both boys and girls are taught using CAI.

4.1 Students' level of Academic and Gender Achievement before Treatment

The aim of the pre-testing the groups was to ascertain whether the students selected to participate in the Experimental group and Control group had comparable academic characteristics. Experimental group 1 and Control group 1 students were exposed to CAT pre-test before the application of treatment. Table 3 shows the descriptive statistics and t-test analysis of the two groups.

Table 2: Descriptive and Independent Sample t-test of Pre-treatment scores in CAT

Variable	Group	N	Mean(Max=40)	Std. dev	df	t-value	Sig
CAT	Experimental 1	53	23.23	3.750	88	1.314	0.192
	Control 1	56	22.23	4.125			

The t-test analysis reveals that the CAT pre-test mean scores of both Experimental group and Control group were not significantly different at 0.05 alpha level ($t(88) = 1.314$, $p > 0.05$). Therefore, the groups were deemed similar on CAT measure and had comparable characteristics, hence homogenous. A similar test was done based on gender achievement in chemistry and the results are shown in table 3.

Table 3: Descriptive and Independent Sample t-test of CAT Pre-treatment scores in CAT by Gender

Variable	Gender	N	Mean(Max=40)	Std. dev	df	t-value	p-value
CAT	Female	56	22.33	4.125	88	1.302	.190
	Male	53	23.23	3.750			

The t-test analysis shows that the CAT pre-test mean scores for boys and girls students was not significantly different, $t(88) = 1.302$, $p > 0.05$. This implied that the male and female students' samples were similar on CAT measure before the exposure of the treatment. Hence homogenous.

4.2 Effect of CAI on Students' Academic Achievement in Chemistry as compared to CIM

The study aimed at investigating whether there was significant difference in students' achievement in Chemistry when taught with CAI and CIM ($H_0 1$). There were four groups that were involved in the study, two Experimental and two Control groups. The Experimental groups were exposed to the treatment (CAI) and the Control groups were not exposed to the treatment. At the end of the treatment period, all the four groups did a Chemistry achievement test (CAT). The scores of CAT were analyzed using descriptive statistics, ANOVA and ANCOVA and the results were indicated as in Table 4, Table 5 and Table 6.

Table 4: Descriptive Statistics of Overall Post-test Scores in CAT

Variable	Group	Mean(Max=40)	N	Std. Deviation
CAT Post-test	Experimental group1	25.60	45	3.360
	Control group 1	16.07	45	4.298
	Experimental group 2	26.59	46	4.145
	Control group 2	14.71	38	4.959

From Table 4, it is apparent that the average CAT post-test scores of Experimental groups were relatively higher than those of the Control groups. For instance, the mean scores for Experimental group 1and 2 were 25.60 and 26.59 while Control groups 1 and 2 mean scores were 16.07 and 14.71 respectively. This indicates that students who were taught using Computer Aided Instruction performed better than the students who were taught using Conventional Instructional Methods. In order to establish whether there was significant difference between the group means, OneWay ANOVA test was performed on CAT Post-test scores and the results obtained were as shown in Table 5.

Table 5: OneWay ANOVA of CAT Post-test scores

Source of variation	Sum of Squares	df	Mean Square	F	p-value
Between Groups	4986.380	3	1662.127	94.421	.000
Within Groups	2992.568	170	17.603		
Total	7978.948	173			

The results in Table 5 show that the difference in Chemistry achievement post-test mean scores of the

students between the Experimental and Control groups was significant, F (3,170) = 94.42, p < 0.05. In order to do away with any initial academic differences among the groups, ANCOVA test was conducted using students' science KCPE examinations marks as a covariate. A covariate variable is a continuous variable that is not part of the main experimental manipulation but has an influence on the dependent variable. The ANCOVA results are indicated in Table 6.

Table 6: ANCOVA of the CAT Post-test scores

Source of variation	Sum of Squares	df	Mean Square	F	p-value
KCPE science marks	105.349	1	105.349	6.166	.014
Group	2646.916	3	882.305	51.645	.001
Error	2887.219	169	17.084		

The ANCOVA test results in Table 6 reveals that the difference in CAT-posttest mean scores between the Experimental and Control groups after controlling for the effect initial academic difference among students using KCPE science marks was significant, F (3, 169) = 51.65, p < 0.05. Thus, $H_0$1, which stated that there is no significant difference in Chemistry achievement scores between students who are taught using CAI and those taught using CIM was rejected.

The study revealed that the students who were taught Chemistry with CAI performed better that those who were taught with conventional instructional method The findings of this study are consistent with the results of Serin (2011) which found a statistical significant difference between the students who received the computer based science and technology instruction and non- computer based in the achievements. Also, the findings of the this study concurs with another study conducted by Olga (2008), that revealed significant difference between the groups on the post achievement tests in favor of experimental group that received computer assisted instruction in Mathematics. The research findings of Ahiatrogah, Madjoub & Bervell (2013) provides similar results with those of the current study. The findings of this study are in agreement with Jesse, Twoli & Maundu, 2014) study, which showed that the learners taught through CAI performed significantly better than students taught through conventional instructional techniques. The findings of this study are in consistent with the findings of Nduati (2015) which indicated a significant improvement in Chemistry performance for students from the experimental group who were exposed to computer assisted learning than those students from control group, who were not exposed to computer assisted learning.

Further, the findings of this study are also in agreement with Kareem (2015) study that investigated the effects of introduction of CAI in Biology compared to the conventional method of teaching on senior secondary school students' achievement and the results revealed that CAI improved students' academic achievement in Biology. In addition, the findings of this study concurs with Olakanmi, Gambari, Gdodi & Abalaka (2016) study findings which revealed that the students who were taught Chemistry with computer assisted instruction had higher achievement than those in conventional teaching methods. The CAI program is a powerful tool that provides immediate feedback to learners for the answers of the exercises, quizzes and assignments. This factor made the students taught Chemistry with CAI to have improved academic achievement in the subject than those taught with CIM. This, then implies that the type of teaching methods employed is one of the factor that affects students' academic achievement.

4.3 Students' achievement in Chemistry by Gender when exposed to CAI Method

The study aimed at establishing whether there was significant gender difference in Chemistry achievement when students were taught with CAI ($H_0$2). Experimental group 1 comprised of 45 boys while Experimental group 2 had 46 girls who were taught with CAI. In order to establish whether the two groups (boys and girls) were significant different, an independent sample t-test was performed to compare the gender achievement in Chemistry.

Table 7: Independent Sample t-test of Post-test scores in CAT by Gender

Variable	Gender	N	Mean(max=40)	Std.dev	t-value	df	p-value
CAT	boys	45	25.60	3.360	-4.112	89	.000
	Girls	46	26.59	4.145			

The t-test analysis reveals that the difference between the CAT mean scores for boys (Mean=25.60, SD=5.9) and girls (Mean=26.59, SD=4.1) was significant, t (89) = -4.11, p < 0.05. Thus, $H_0$2, which stated that there is no significant gender difference in Chemistry achievement when students are taught with CAI, was rejected. This, therefore suggests that the achievement in Chemistry by gender is specifically different, with girls achieving higher scores in Chemistry than boys when taught using CAI.

This study revealed that girls obtained higher Chemistry achievement scores than boys when taught with CAI. The findings of this study concur with study of Klainin & Fenshams (1987) which showed that Thai girls perform better than boys in Chemistry. The findings of this study also find support from FAWE (1999) reports that noted that girls excel academically and are better to face the challenges that hinder their achievement when they have favorable learning environment. From the results of the present study, it is clear that girls performed

better than boys in Chemistry when taught with CAI approach. The CAI provides a creative and favorable learning environment. Favorable environment of learning enables the girls to face the challenges to learning. For example, girls in conventional classroom may feel shy to answering oral questions as opposed to boys. However, in the CAI classroom, the computer program has in-built evaluative questions and scores that assesses the answers of the student; if the student answers match with the correct answers the program offers praise accompanied by music and animation, if the student answers does not match with the correct answer, the program offers an explanation and presents similar problem. In a CAI environment, the girls, then can answer many questions and also make several trials to each question without shying off. These factors made the girls to perform better than the boys in Chemistry. Thus, CAI approach can play a vital role in bettering the girls' achievement in Chemistry more than boys.

5. Conclusions and Recommendations

Based on the findings of this study, the following main conclusions were drawn:

The study revealed that the students who were taught with CAI obtained higher scores in Chemistry than those taught with Conventional Methods. This implies that use of Computer Aided Instruction improves students' achievement in Chemistry as it stimulates memory for better coding and understanding of concepts. Therefore classroom teachers, should shift from conventional way of teaching to the use of CAI. By using CAI, classroom teachers can and do make a significant improvement in students' academic achievement. Further, the study revealed that girls obtained higher Chemistry mean scores than boys when taught with CAI. This implies that use of CAI improves girls' achievement in Chemistry more than it does for boys. Therefore, girls gain more than boys when taught with CAI, hence girls are more receptive to stimulus variations. Thus, classroom teachers, especially those in girls' schools should adopt CAI in their teaching because it has positive impact of bettering girls' performance in Chemistry.

The government of Kenya should provide adequate infrastructure and equipment for CAI, including computer hardware and software (CAI) in all schools. Availability of adequate computer aided instruction software in schools will enable the Chemistry teachers to utilize CAI approach in the teaching and learning processes. School administrators should endeavor to provide an enabling environment for the use of CAI. This they can do by either providing or expanding existing ICT resources or facilities in schools to help foster enhanced CAI. They should also provide incentives to motivate chemistry teachers so as to empower them to better use CAI in their teaching and learning activities.

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