Kentucky Journal of Excellence in College Teaching and Learning

Volume 12 Article 4

June 2015

Enhancement of Science Performance through Computer -Assisted Instruction among Selected Secondary School Learners in Kenya

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Enhancement of Science Performance through Computer-Assisted Instruction among Selected Secondary School Learners in Kenya *RESEARCH*

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Abstract

The performance of learners in Science in Kenyan secondary schools has been consistently low over the years. Many factors contribute to this poor performance and among them is the inappropriate teaching approaches that are teacher-centered rather than learner-centered. The purpose of the present study was to investigate the influence of instructional methods on efficiency of content delivery to the learner and eventually the learner's improved performance in science. Quasi-experimental design was used, based on the performance in science when the Conventional Instructional Techniques (CIT) are used and when a combination of computer-assisted instruction (CAI) and conventional instructional methods are used. Biology, Chemistry and Physics teachers and Form Two learners from six provincial secondary schools situated in the greater Embu district were involved the research. Data collected using Standard Students Assessment Tests (SSAT) was analyzed in order to uncover whether there was a significant difference in learners' science performance before and after the treatment. The study found out that learners taught through CAI performed significantly better than learners taught through CIT in science. Based on this study, it was concluded that use of computer-assisted instruction improves secondary school learners' performance in science. This paper ends with some recommendations for further research.

Keywords: computer-assisted instruction, conventional instruction techniques, science, performance, teaching approach

Introduction

Biology, Chemistry and Physics are the three pure science subjects offered in Kenyan secondary schools curriculum (KIE, 2002). In the national examinations conducted by the Kenya National Examinations Council (KNEC), the three subjects are categorized in group two, with Biology taking code 231, Physics taking code 232 and Chemistry taking code 33. According to the Programme for International Student Assessment (PISA, 2002), the performance of a country's students in science subjects have implications for the part that country will play in tomorrow's advanced technology sector, and for its general international competitiveness. The report also emphasized the critical role of science subjects in the socio-economic development of a country. Despite this critical role, the performance of students in science subjects in Kenya's secondary schools has continued to be low for many years. According to Musyoka (2004), it is common knowledge that students' achievement in science subjects is wanting, as reflected by the performance in national examinations. The feedback from formal examinations and observations by stakeholders constantly indicate a shortfall in these subjects.

According to Munywoki (2004), parents, government, and other stakeholders continue to invest heavily in the education of young Kenyans every year in the hope that the inputs will result in better outputs. The immediate expected output from the education system is good performance in examinations. Learning achievement was adopted as a key indicator of the quality of education during the 1990 World Conference on Education for All (EFA) in Jomtien, Thailand (UNESCO, 2000). The low performance trend in science subjects in Kenyan secondary schools is a cause of worry to many stakeholders. As outlined in the KNEC reports (2006 – 2011), the performance of students in Biology, Chemistry, and Physics has remained below average (Table 1).

Table 1

Percentage means scores of Biology, Chemistry and Physics from 2005 – 2010 in Kenya.

Subjects	2005	2006	2007	2008	2009	2010	Average mean scores
Biology	32.01	29.84	44.70	30.32	27.20	29.23	35.23
Physics	35.99	40.82	42.23	36.71	31.33	35.13	37.04
Chemistry	29.44	27.01	27.69	22.74	19.13	24.91	25.15

Note. From the Kenya National Examinations Council Reports (2006, 2007, 2008, 2009, 2010 and 2011)

This poor performance in science may be attributed to several factors (Musyoka, 2004; Muraya & Kimamo, 2011), including student attitude towards the subjects which they perceive as difficult; inappropriate teaching approaches that are teacher-centered rather than student-centered; inadequate mastery of teaching subject by some teachers; inadequate teaching and learning resources; poor terms of service for teachers, and heavy teaching loads. According to Fraser and Walberg (1995), appropriate instructional activities can be effective in promoting the development of logical thinking, as well as the development of some inquiry and problem-solving skills.

For effective teaching and learning to occur, the teacher should use an efficient approach of conveying the information to the learner (Brown et al., 1982). In order to increase students' motivation to learn science, a variety of innovative instructional techniques can be used (Fraser & Walberg 1995). Various studies have suggested that inappropriate teaching approaches employed by science teachers in Kenyan secondary schools may be one of the contributing factors to poor performance in science. According to Kolawole (2008), teacher-centered teaching approaches are dominant at the secondary school level, where the teacher presents information to students in a lecture and students complete assignments out of the class and later take examinations to demonstrate their degree of understanding and retention of subject matter. Most of the instructional methods the teachers use in our classrooms are usually teacher-centered and hence give fewer opportunities or roles to play in the classroom discourse. Apparently, such situations tend to limit students' active participation (Kiboss, 2000; Tanui 2003). The UNESCO - Education for All, Global Monitoring Report (2005) notes that practitioners broadly agree that teacher-dominated pedagogy, where students are placed in a passive role, is undesirable, yet such is the norm in the vast majority of classrooms in Sub-Saharan Africa.

To improve academic achievement, the teaching approaches adopted by a teacher should make learning more learner-centered so as to promote imaginative, critical and creative skills in the learners, thereby producing better achievement in instructional objectives. The learner-centered teaching and learning approaches actively engage the learner in the learning process for effective mastery of the subject content matter and promote a positive attitude towards the subject (Ministry of Education Science and Technology, 2011). KNEC (2011) noted that schools should use e-learning to give students access to diversified information that can assist them in understanding science concepts.

According to Wambugu and Changeiywo (2008), the teaching approach that a teacher adopts is one factor that may affect students' achievement; therefore, using an appropriate teaching approach is critical to the successful teaching and learning of science. Many topics in science may require innovative instructional methods such as computer-assisted instruction (CAI) to foster the learners' understanding and facilitate adequate coverage of all the science processes and concepts (Jesse, 2011). In Chemistry, for example, neither practical nor theory teaching can effectively cover certain areas like preparation of poisonous gases such as chlorine and carbon II oxide. In Biology, areas that deal with the functioning of the body parts are very difficult to explain since no practical activity can be done to illustrate them. In 2006, KNEC noted that questions like *Describe how the human kidney functions* were poorly done. The KNEC (2006) report pointed out that details of what happens at the nephron were lacking, and there was confusion regarding what happens in the loop of henle and what ultra filtered means. These topics can easily be taught using computer simulation and animations, making it easier for a learner to understand. CAI would even make it easier to cover the science syllabus since many practical activities are already simulated and learners can replay them even in the absence of the teacher. A positive relationship exists between syllabus coverage and performance at National Examinations level (Amadalo, Shikuku, & Wasike, 2012).

Computer-assisted instruction (CAI) refers to teaching and learning through computer-based programs that mostly involve drill and practice, tutorial and computer simulation activities offered either by themselves or as supplements to traditional, and teacher-directed instruction (Stennet, 1985). CAI can provide an effective supplement to the teacher (Kauchak & Eggen, 1993). In recent years, CAI has witnessed great development in many countries. Kinnaman (1990) observes that in the U.S., for example, the number of schools owning computers increased from approximately 25 percent in 1981 to virtually a 100 percent by the end of the decade. In Kenya, however, the use of CAI is not widespread. According to Wragg (2000), studies indicate that most teachers feel threatened by the computer because it forces them to organize their classrooms differently, which reduces their control and makes their normal approach of monitoring progress difficult to implement. Selwyn (1987), Olson (1992) and Kiboss (1997) also observed that teachers feel bereft of influence because they feel unable to monitor what goes on and are uncertain about their proper role in the class. Their fear of losing control or power in the classroom likely influences their negative perception of CAI in their classrooms.

A lot of research and studies have been done on CAI teaching and most of them recommend it as a very useful instructional tool. Capper and Copple (1985) indicate that the single-best-supported finding in the research literature is that the use of CAI as a supplement to traditional teacher-directed instruction produces achievement effects superior to those obtained with traditional instruction alone. Rupe (1986) added that student learning rate is faster with CAI than with conventional instruction. According to Kulik (1987), students receiving CAI learn better and faster, and students' scores on delayed tests indicate that the retention of content learned using CAI is superior to retention following traditional instruction alone. Dalton and Hannan (1988) indicate that while both traditional and computer-based delivery systems have valuable roles in supporting instruction, they are of greatest value when complementing one another. As such, the successful integration of CAI into the teaching and learning of science depends on teachers embracing the new innovation, making informed judgments about the suitability of CAI to meet their particular teaching and learning goals, and considering CAI in their search for new instructional approaches. There was therefore a great need to investigate the effects of introducing CAI into science instruction in Kenyan secondary schools.

Methodology

Research Design. A research design is a structure of research. It is the 'glue' that holds together all the elements in a research project (Kombo & Tromp, 2006). This study used a two-group quasi-experimental pretest-posttest design. Form Two classes in three out of the six provincial schools that offer computer studies in Embu district were randomly assigned the experimental group while the Form Two classes in the other three provincial schools were labeled the control group. This was based on the academic performances and learning facilities, especially the number of computers available in the computer laboratories. Both groups were measured before the treatment was given by use of standard student test (pre-test). The experimental group was then exposed to CAI in the computer laboratories (treatment) while the control group was only exposed to the normal Conventional Instructional Techniques in the normal classes (no treatment). This is illustrated in Figure 1.

Figure 1. Illustration of the Research Design

N	o_1	x	o_3
N	o_1	x	o_3
		KEY	
N		-	Randomized Groups
X		-	Treatment
⊗		-	No treatment
O_1 and o_2		-	Pre-test
O_3 and o_4		-	Post-test

CIT entailed application of commonly used instructional methods in science such as lecture, teacher demonstrations and practicals. CAI involved instruction through up-to-date instruction software, through which students could learn their Biology, Chemistry, and Physics lessons in the computer laboratories. After a period of four weeks, the two groups were measured again by use of another standard test (post-test).

Target Population. The target population in this study was teachers who taught science subjects and students who took Biology, Chemistry, and Physics in secondary schools that offered computer studies in the Embu district. There were eleven secondary schools that offered computer studies in Embu district. These schools had a population of 5,219 students with 1,371 being Form Two students. The total number of science teachers in the eleven schools was 73, where seventy of them taught the Form Two classes. Table 2 shows the total number of students and science teachers in the eleven schools, the total number of students in Form Two, and the number of science teachers involved in teaching the Form Two classes. The percentage of the schools, teachers, and students that were targeted by the study is also shown on Table 2. This meets the recommended percentage in statistical terms, which is ten percent (Orodho & Kombo, 2002).

Table 2
Target schools, Teachers and Students

Subjects	Total number	Percentage
Secondary schools that offer computer studies	11	100%
Schools involved in the study	6	55%
Population of students in the eleven schools	5219	100%
Population of Form Two students in the eleven schools	1371	26%
Science teachers in the eleven schools	73	100%
Form Two science teachers in the eleven schools	70	96%

Note. From Embu District Education Office and pre-study survey.

The Sample and Sampling Procedures. Purposive sampling was used to select secondary schools that offer computer studies in Embu district. This was because a key resource that comprises computer laboratories was required for the CAI lessons. The experimental group also required learners with basic computer skills. The six provincial schools that offered computer studies in the district were selected for the study. This was to ensure that the pre-requisite skills or the knowledge level of the students in the science subjects was almost the same. In the sample schools, the Form Two classes were purposively selected for the study. This was because the learners at this level had fully adapted to the environment, but they have not yet selected the subjects that they will be examined on for the Kenya Certificate of Secondary Education examination. The Form Two classes in three of the six provincial schools were randomly assigned the experimental group while the Form Two classes in the three remaining provincial schools were assigned the control group. Each study school therefore had either three experimental groups or three control groups, resulting in a total of eighteen study groups in all the study schools.

Research Instruments. Written assessment tests (standard students' assessment tests) were used to measure the learners' performance in the three science subjects that were being studied. Two types of assessment tests were used: the pre-test and post-test. Pre-test assessment tests were used to measure the performance of both the experimental and the control group before the treatment was administered. This was to ensure that both groups possessed relatively equal ability. The pre-tests focused on the following content: In Biology, *Nutrition in Plants and Animals*; in Chemistry, *Air and Combustion* and *Water and Hydrogen*; and in Physics**,** *Electrostatic I, Cells*, and *Simple circuits*. These topics were selected because they are the last topics in form one and this study was carried out in the first term. Post-test assessments were used to measure the performance of the learners in both groups after the experimental group had received the treatment.

The post-tests were constructed from the following topics: In Biology, *Transport in Plants and Animals*; in Chemistry, *Structure of the atom* and the *Periodic table*; and in Physics, *Magnetism*. These topics were selected because they are the first topics in form two and this study was carried out during first term of school. Pre-tests and post-tests were built from different topics to ensure that achievement in the post-test was not based on the previous knowledge. Both pre-test and post-test were developed by a panel of five teachers per subject who are specialized in teaching that particular subject at secondary school level for a period of no less than five years. Those teachers were also involved in ensuring that the tests they constructed were standard. The teachers in those panels were selected from other schools that were not involved in the study to avoid leakage of the tests before they were done.

Content validity of the assessment tests was determined using the content validity formula developed by Lawshe in 1975. In this case, five panelists were selected from subject teachers who have at least five years of experience in teaching the subject. The panelists in each subject went through each item in the tests indicating whether the item was essential, useful but not essential, or not necessary to performance of the construct. The formula CRV = $(n_e – N/2) / (N/2)$ where CRV=content validity ratio, n_e=number SME panelists indicating essential and N= total number of SME panelists involved. This formula yields values that range from +1 to –1 where positive values indicate that at least half the SME panelists rated the item as essential. In the pre-test, the mean CRV across items in Biology was 0.94, 0.95 in Chemistry, and 0.97 in Physics. In post-test, the mean CRV across the items in Biology was 0.99, 0.96 in Chemistry and 0.93 in Physics. This means that at least half of the SMEs in each subject rated each item as essential and therefore the content validity ratios were positive.

Reliability of the assessment tests was determined using the Split-Half method. In this method, the total number of items were divided into halves by assigning the odd numbered items to one half and even numbered items to the other half of the test. A correlation was then taken between the two halves. A statistical correlation to estimate the reliability of the whole test was then done using Spearman-Brown prophecy formula: Pxx" = 2Pxx'/1+Pxx' where Pxx" is the reliability coefficient for the whole test and Pxx' is the split-half correlation. In pre-tests, the Pxx" and Pxx' for the three subjects were as follows: Biology had Pxx" = 0.87 and Pxx' = 0.93, Chemistry had Pxx"

= 0.75 and Pxx' = 0.86, while Physics had Pxx" = 0.91 and Pxx' = 0.95. In the post-test, the values were as follows: Biology had Pxx" = 0.82 and Pxx' = 0.90, Chemistry had Pxx" = 0.86 and Pxx' = 0.92, while Physics had Pxx" = 0.89 and Pxx' = 0.94. All the subjects had positive reliability values, meaning they could yield consistent results on repeated trials. Little modifications were done, however, on the chemistry pre-test, which had a reliability value of less than 0.9.

Data Collection Procedure. Permission to carry out the research in schools in the Embu district was granted from the National Council for Science and Technology (NCST), a government agency in the Ministry of Higher Education, Science and Technology (MHEST) in Kenya. Sampled schools were then visited to seek permission to carry out the research from the school principals. A meeting with the science and computer studies teachers was then organized, where basic issues about the study and its benefits were discussed. Teachers were requested to explain to their students about the study since it was expected to affect their normal learning programmes.

Data was collected in two stages during the main study. At the beginning of the study, the two research groups were given a standard assessment test (pre-test). The results of this test were obtained and analyzed to ascertain the relative level of both the experimental and the control groups at the beginning. The experimental group was then exposed to the treatment (computer-assisted instruction) for a period of four weeks while the control group continued with the conventional instructional methods. At the end of the four-week period, another standard test (post-test) was given to the two groups and results were recorded.

Results and Discussion

The data obtained during the pre-test and post-test assessment tests was analyzed using means and followed by a t-test. This enabled the researchers to find out whether there was any statistically significant difference between the performance of the experimental and the control groups, both before and after the treatment. This way, it was possible to determine the impact of CAI on performance in science subjects. Statistical Package for Social Sciences (SPSS) was used to facilitate the analysis of the data.

Results for the Pre-test. Data obtained after marking the pre-test were used to calculate the mean, standard deviation, and the standard error of both the experimental and the control groups in all three science subjects. The means for both experimental and control groups were close. This suggests that the samples were of almost equal ability in science. Table 3 summarizes the obtained results.

Table 3
Mean, Standard Deviation and Standard Errors

Subject	Group	Mean	Standard deviation	Standard error
Biology	Experimental	55.04	13.04	1.02
	Control	55.05	12.87	1.09
Chemistry	Experimental	54.59	11.35	0.89
	Control	54.67	12.05	1.03
Physics	Experimental	50.98	12.25	0.96
	Control	51.01	12.38	1.05

The test for the equality of the means was then carried out using the independent samples t-test (Table 4). Equal variances were assumed during the t-test since the levense's significance values for Biology, Chemistry and Physics were 0.74, 0.394, and 0.747, respectively. These values were higher than the α value of .05, that is, p>α. The significant values for the t-test (p-values) were 0.993 for Biology, 0.954 for Chemistry and 0.982 for Physics. Since these values for the t-test were higher than the α value of .05, this implies that there is no significant difference in student performance in Biology, Chemistry and Physics between the experimental and the control groups.

Table 4
Independent Samples t-test for the Pre-Test

Subjects	t	df	significance	Mean difference	Lower limit	Upper limit
Biology	-.009	299	.993	-.014	-3.901	3.874
Chemistry	-.058	299	.954	-.078	-3.580	3.425
Physics	-.023	299	.982	-.033	-3.372	3.659

Results for the Post-test. The mean, standard deviation, and the standard error were calculated in the same way as the pre-test. The means of the experimental groups were found to be much higher than those of the control groups in all three science subjects. Based on this performance, one can infer that the treatment had quite an effect on the experimental group. It can be viewed, therefore, that CAI has a positive effect on the learning of science in secondary schools. The results are presented in Table 5.

Table 5
Means, Standard Deviation and Standard Error of the Post-Test

Subject	Group	Mean	Standard deviation	Standard error
Biology	Experimental	60.27	10.29	0.81
	Control	55.39	10.45	0.89
Chemistry	Experimental	57.84	11.81	0.93
	Control	53.32	12.18	1.04
Physics	Experimental	59.55	1068	0.84
	Control	55.67	9.35	0.80

The independent samples t-test was then used to test the equality of the means. The significance values for the t-test (p-values) obtained were .001 for all three science subjects. Since these values are typically below α value of .05, it therefore implied that there was a significant difference in students' performance in Biology, Chemistry and Physics between the experimental and the control groups. Table 6 provides a summary of the obtained results.

Table 6
Independent Samples t-test for Post-Test

Subjects	t	df	significance	Mean difference	Lower limit	Upper limit
Biology	4.07	299	0.001	4.88	1.77	7.99
Chemistry	3.26	299	0.001	4.52	0.93	8.11
Physics	3.32	299	0.001	3.88	0.85	6.90

Comparison of the Means Difference between the Experimental and Control Groups. In the pre-test, the mean difference between the experimental and the control groups was -0.014 in biology, -0.078 in chemistry, and -0.033 in physics. The average means difference between the experimental and the control groups during pre-test was therefore -0.041. This value is very small, implying that the two groups were of relatively equal ability at the beginning of the study.

In the post-test, the mean difference between the experimental and the control groups was 4.893in biology, 4.60 in chemistry, and 3.911in physics. The average mean difference in the three subjects during the post-test was therefore 4.468. This value is visually large enough and therefore indicates a difference between the experimental and control groups in terms of performance in the tests. The means difference between the two groups is summarized in Table 7.

Table 7
Comparison of the Means Difference between the Experimental and the Control Groups

Subject	Pre-test	Post-test	Difference
Biology	-0.014	4.879	4.893
Chemistry	-0.078	4.522	4.600
Physics	-0.033	3.878	3.911

Conclusion

In the pre-test, a t-test revealed no significant difference between the performance of the experimental and the control groups in Biology, Chemistry and Physics. In all three cases, the p-values were greater than α values (p>α). In the post-test, a t-test revealed a significant difference between the performance of the experimental and the control groups in Biology, Chemistry and Physics. In all three cases, the p-value was smaller than the α values of 0.05 (p<α).

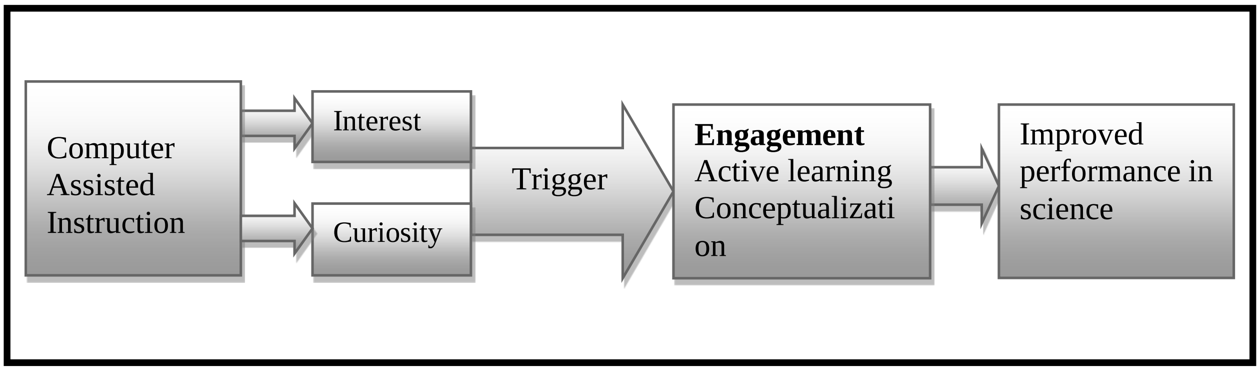
A comparison between the mean difference in the two groups revealed that in the pre-test, the performance of the experimental and the control groups was almost equal since the mean differences in Biology, Chemistry and Physics were 0.014, -0.078, and -0.033, respectively. In the post-test, a wide difference between the performance of the experimental and the control groups was noted, with the mean differences of Biology, Chemistry, and Physics being 4.879, 4.522, and 3.878, respectively. CAI therefore improves the achievement in science.

This finding confirms the observations by Rupe (1986) that, in addition to enabling students to achieve at higher levels, CAI also enhances learning rate, leading to better performance. In addition, Fraser and Walberg (1995) noted that the use of computers for instruction resulted in increased student interest, cooperation, achievement in science, and coverage of science curriculum.

Because the improvement in science performance by the experimental group resulted from the application of CAI in science lessons, it appears that the instructional methods used by teachers influence the performance of the learners. According to Kulik (1987), students receiving CAI learn better and faster, and students' scores on delayed tests indicate that the retention of content learned using CAI is superior to retention following traditional instruction alone. Wambugu and Changeiywo (2008) also noted that the teaching approach that a teacher adopts is one factor that may affect students' achievement, and therefore use of an appropriate teaching approach is critical to the successful teaching and learning of science.

From classroom observation, it was evident that the students under CAI looked keen and showed a lot of interest during lessons. They were curious to observe what was coming next. This sort of expectation created readiness to learn and hence to be engaged. It appears, therefore, that interest plays an important preliminary role in CAI and triggers learners' engagement in creating an enhanced environment for a science teacher to positively exploit (see Figure 2).

Figure 2. CAI transmission in learning secondary school science



This inductive thinking has been supported by some scholars (e.g., Marilyn et al., 2010), who indicated that participative engagement in particular creates an enjoyable environment, which provides the catalyst for active learning and conceptualization in science. It is assumed that the engagement role is responsible for the improved performance.

The above findings challenge the traditional teacher-centered approach that dominates Kenyan secondary school classrooms, including science education lessons. In the interest of forming a good technological base for future generations, it is imperative that science teachers embrace the integration of technology in classroom practice. This should hopefully translate to improved learner performance in KCSE examinations, thereby paving a way for science-based careers later in life.

This paper concludes with some suggestions for further research. First, the role of interest in CAI is central, especially as schools become technology inundated. It is often experienced that interest can be short lived. As a mediating factor, if interest tapers, the whole process 'dies.' There is need, therefore, to determine the long-term effect or sustainability index of this factor by designing a longitudinal study. Second, gender effect was not addressed in this study. We recommend that a study be carried out to determine the effect of CAI on gender.

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