

**EFFECTIVENESS OF COMPUTER BASED TECHNOLOGY INTEGRATION
IN TEACHING AND LEARNING OF GENE CONCEPT AMONG HIGH
SCHOOL STUDENTS, KENYA.**

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ABSTRACT

The main goal of this study was to determine whether the integration of computer-based technology including computer animations and illustrations in teaching and learning of the gene concept could enhance students' understanding of the gene concept. The population of the study was the entire Form Four biology students who have studied biology for four years at public secondary schools in Kakamega Central District of Kenya. The schools were selected by stratified random sampling to include provincial girls', provincial boys', and district mixed secondary schools. Simple random sampling was used to select 240 Form Four biology students. The control groups (C1, C2 and C3) were taught in a conventional manner whereas the experimental groups (E1, E2 and E3) received instruction that integrated computer animations and illustrations. Gene concept administered was the same for both pre-test and post-test for a period of four weeks. Gene concept Achievement Standardized Test and Gene Concept Multiple Choice Test were used as instruments for data collection. The pre-test and post test scores in the pilot study indicated a positive correlation using Pearson's product moment correlation coefficient (r) of 0.79. Thus the instruments were reliable. With the help of SPSS data analysis was conducted using ANOVA (F-test), and T-test. The results were tested using ANOVA at $\alpha = 0.05$ level of significance. The findings in the study showed that the integration of computer-based technology in teaching and learning improved students' achievement scores and understanding of the gene concept.

Keywords: Affordances, computer based integration, gene concept, integration, students' achievement, scaffolding.

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Background of the Study

A survey by the Kenya National Examinations Council (KNEC) over a period of six years revealed that students' academic performance in secondary school biology has been generally poor (KNEC Reports, 2003-2008). The Strengthening of Mathematics and Science in Secondary School Education (SMASSE) report (2000) reveals that inappropriate teaching methods led to poor understanding and performance in biology and in other science subjects at selected secondary schools. The report specifically pointed out that poor understanding of science content and a lack of innovative skills lead to poor performance in practical tasks by the students. The gene concept is one such area in biology that presents learning difficulties to the students. A review of literature on this issue indicates students in many other countries in the world experience learning difficulties of the gene concept (Hounshell and Hill, 1989).

The Gene concept is a central concept in genetics and a thorough understanding of it is essential for understanding other related fields of biology such as biotechnology, genetic engineering, recombinant DNA technology, and cell and molecular Biology. However, the teaching and learning of the gene concept has continued to provide a challenge to both teachers and students of biology at secondary schools of Kenya. The Kenya National Examination Report (KNEC) report (2004) observes that students had learning difficulties in genetics. For example, they could not correctly use the conventional signs and symbols in genetics or distinguish among gene, trait and chromosome. The KNEC report (2008) for the Kenya Certificate of Secondary Education (KCSE) examination sat in 2007 also noted that students failed to identify nitrogen bases as components of genes hence could not explain how deletion and inversion occur in genes. The majority of students confused chromosomal mutation with gene mutations. Questions testing experimental design in genetics were performed poorly indicating lack of practical approach to teaching.

The gene concept is taught at Form Four level when most teachers are eager to complete the syllabus hence the approach is largely teacher-centered. Consequently, most teachers teach genetics theoretically. The teachers perceived genetics to be difficult both to teachers and students and lacked sufficient practical activities or experiments in the biology teachers' guides (SMASSE report, 2000). The topic is also wide which makes teachers rush over to cover the topic thus stifling students' ability to critically analyze situations and sustain their interest in the topic approach defeats the key goal of biology teaching: to develop more effective and scientifically aligned strategies to assist

high school students understand the key concepts in the biology curriculum.

Kesidou and Roseman (2002) observed that curriculum materials have a major role in teaching and learning, and many teachers rely on them to improve their pedagogical skills in the delivery of their content. Dreyfus and Halevi (1991) showed that the use of computer programs provided an open learning environment that allowed pupils to explore learning tasks within a framework, where the teacher works as a guide. In such an environment, even weak students are encouraged to learn in depth with many difficult biology concepts. Alternatively, Hoyles and Noss (1992), as a result of their studies in Logo based micro worlds, suggested that teachers restrict the software environment within which pupils may explore and within which pupil autonomy and mathematical expression may take place. In addition, Michel *et al.* (1999) suggest that allowing pupils to make video clips can develop their power of observation and open new perspectives for their understanding of scientific concepts. This is because pupils need to think of what should be recorded in order to explain a concept.

The quality of learning outcomes depends on the interaction between the teaching styles and methods used by the teacher to create suitable learning environment (Entwistle, 1998). Research has shown that the use of a wide variety of resources and approaches improves students' interests in biology and facilitates the learning of difficult concepts such as those encountered in genetics. Computer based simulations (CBS) can be developed for the teaching and learning school biology as a part of classroom innovation in this direction. Computer assisted instruction (CAI) increases students' achievement and develops more positive attitudes in high school biology course (Hounshell and Hill, 1989). Computer-based instruction simulations (CBIS) programs have also been developed for the teaching and learning of several concepts with high cognitive demand as well as those considered as controversial or dangerous to teach and learn through regular methods. The correct use of the technology therefore proved to be crucial to the teachers' success in encouraging learners to adopt hands-on approach to learning (Goos *et al.*, 2003). Although the government of Kenya has made efforts to in-service biology teachers through initiatives such as SMASSE, no marked improvement in the students' performance in genetics has been observed. The traditional pedagogical practices used by the teachers in the teaching and learning of the gene concept underscore the students' poor understanding in area resulting into poor performance and loss of interest in genetics. The teacher's own pedagogical beliefs and values can play an important

role in shaping technology-mediated learning as well as reinforcing existing teaching approaches. The continued difficulties associated with the learning of gene concept amid efforts by the governments to promote best practice pedagogy necessitate this study.

Purpose of Study

The purpose of this study was therefore to determine the effectiveness of integration of computer based technology versus the conventional methods in the teaching and learning of the gene concept in biology at public secondary schools in Kenya. The tested hypotheses were:

- (a) The Computer-based technology has no effect on student achievement scores in the learning of the gene concept; and
- (b) Computer-based technology does not affect students' understanding of specific sub concept of gene concept.

Conceptual Framework

The use of computers to support constructivist pedagogy has been shown to be effective (Dreyfus and Halevi, 1991). The conceptual framework that guided this study is therefore based on the *perspectives interactions paradigm* which focuses on evaluating the interactions between three key actors: pupil(s), teacher and designer (of the software). The interactions must take place for conceptual learning to occur under constructivist learning theory. As shown in Figure 1, at the discursive and interactive level, the model implies that the teacher's theoretical ideas about their subject lead to specific ways of passing that knowledge (articulation) to the pupils. The pupils provide feedback to the teachers about their understanding, which affects the teachers' ideas about how to improve explanations and the quality of learning tasks for the students. The teacher in this process must call upon his/her scaffolding skills to develop tasks that support students' learning. From the designer to the teacher, the teacher uses the software apparatus such as computer, CD-ROM, projector, flash disks to develop tasks and *scaffolds* that improve and extend their learning. The computer provides *affordances* that enable the teacher and the student interact in classroom by using the software whereby learners create their knowledge and promote independent thinking. Pupils' capability with ICT will also affect their capability for independent learning, their meta-cognitive skills, their own perceptions of the learning objectives for a particular lesson and their perceptions of the value of ICT for their learning.

From the framework, the independent variable was computer based technology model while

the dependent variable was the achieved scores.

This model can help teachers and teacher educators acquire a better understanding of the ways in which teachers' pedagogical practices might be affected by feedback from pupils and interactions with ICT environments. The framework can be applied at any level of the learning process. These interactions involve problem-based learning and teaching strategies including experiments, discovery learning, inquiry learning and reflective thinking.

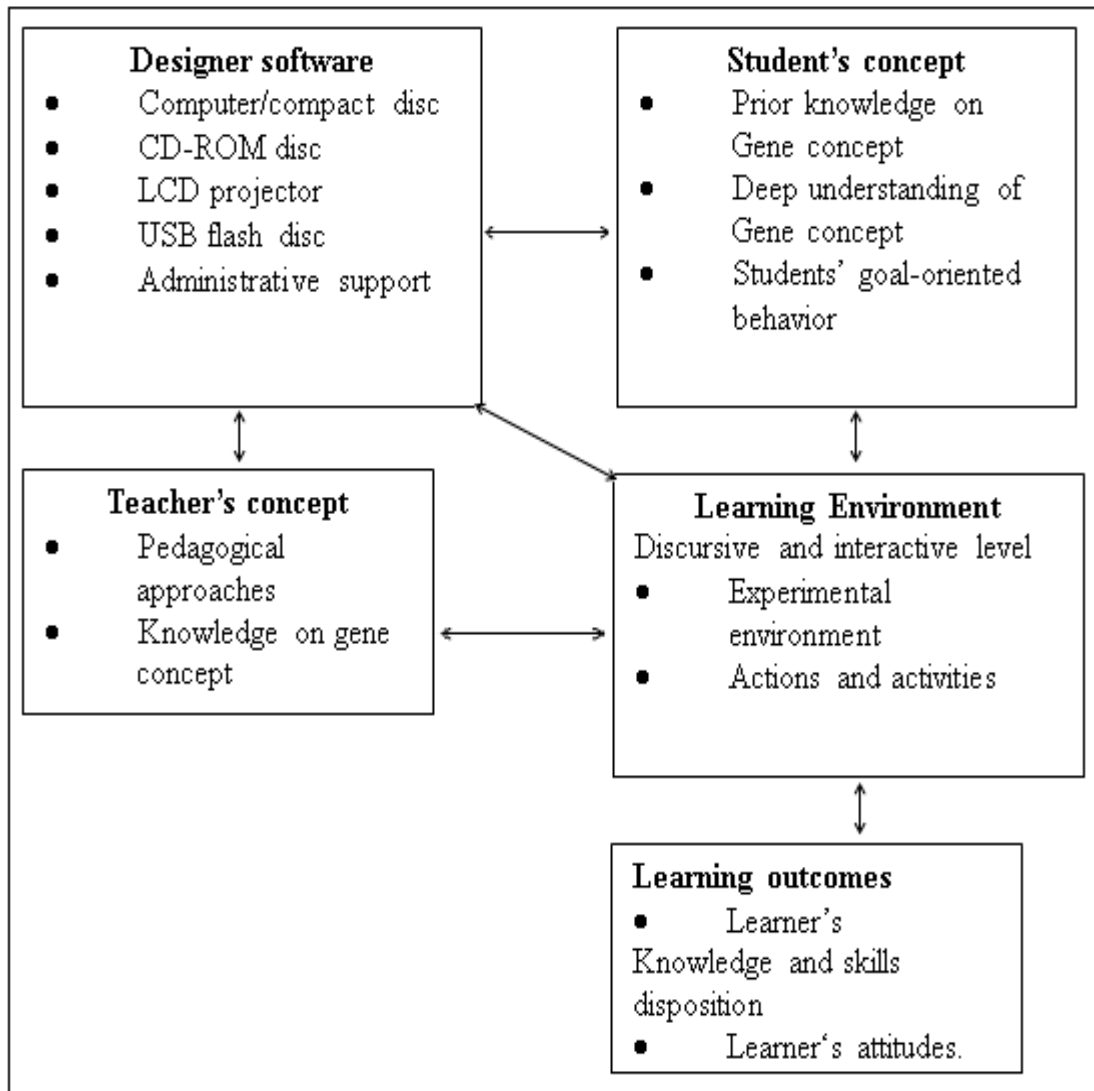


Fig 1: The Conceptual Framework for Teaching and Learning the Gene Concept

METHOD AND MATERIALS

Population and Sample

The study was carried out in Kakamega Central District of Kenya. The target population was the entire Form 4 biology students at the public secondary schools. The Form 4 students were selected for the study since this is the gene concept is taught at this level in the secondary school curriculum.

Purposive sampling was used to select seven schools that had computer laboratories. Stratified random sampling was used to select three schools out of the seven with one school in each category, that is, one provincial girls' only, one provincial boys' only, and one district mixed gender schools. The students were selected using simple random sampling technique whereby 240 Form 4 students of biology were picked from the three schools.

Research Design and Treatment

The study employed the true experimental research design. Random assignment of subjects to control and experimental groups was conducted in the schools followed by treatment (computer-based simulations) in a real biology classroom setting.

The experimental groups (E1, E2 and E3) were taught the gene concept by the researcher for three weeks using computer based technology (CBT) after the pretest. The experimental groups were taught the gene concept through a computer simulations experiments. The CBT approach involved using CD-ROM and USB flash disk containing downloaded learning activities on the gene concept. These materials were assembled in a biology laboratory together with computers and LCD projector carried by the researcher and computer technician. Access to the CBT programme was gained by clicking the mouse at the programme by the researcher. The lesson began with the presentation of the gene concept with information relayed onto the computer screen then relayed on white screen for a larger visualization. In each lesson, learners were presented with experimental tasks in the form of examples from each concept, which required them to attempt, evaluate, and respond either directly via the keyboard or through the attempt in their exercise books. Several scaffolds were given for each task to support students' learning.

The control groups (C1, C2 and C3) also received the traditional pedagogical instruction of

the gene concept involving discussion technique for three weeks. These chiefly focused on teacher explanations and use of students' textbook, followed by discussions and teacher directed questions.

Data Collection and Analysis

The pre-test and post test were administered to both experimental and control groups accordingly. The post test was administered after the appropriate research treatment. The research instruments used in the study were Gene Concept Achievement Standardized Test (GCAT)) and Gene Concept Multiple Choice Diagnostic Test (GCMCDT)(see Appendix A and B). The scores were recorded. The results before and after treatment, were compared to establish the effect of CBT teaching on students' achievement. The scores were subjected to ANOVA inferential statistical analysis using the Statistical Programme for Social Sciences (SPSS).

RESULTS

The results are presented thematically based on the objectives of the study, namely: Students' understanding of gene concept before and after use of CBT; and impact of CBT on students' learning of the gene concept.

Students' understanding of Gene concept before and after use of CBT

In order to determine the effect of CBT on the learning of the gene concept, it was necessary to administer the pretest: Gene Concept Achievement Test (GCAT) and Gene Concept Multiple-Choice Diagnostic Test (GCMCDT) to both experimental and control groups. The results were as summarized in Table 1. The table shows that the overall performance in all categories of schools was below expectation. On the average only 33.6 % of the students (both experimental and control groups) correctly answered the questions on the gene concept while 66.4 % got the answers all wrong. The majority of the students therefore displayed difficulties in understanding the gene concept. Out of the 28 sub concepts of the gene concept, over 50 % of the students did not have difficulties in only three of them, namely, defining the gene, listing types of mutations and their causes. On the other hand, all the sub concepts including determination of sex in human beings and explaining the genetic cause of sickle cell anemia appeared extremely difficult for the students. There was confusion among students on what determines the sex of an organism between a pair of alleles and a pair of chromosomes (overall 53.4% of them failed the test item on Table 1). This was

also evident in distinguishing sex chromosomes and gene mutations disorders.

Table 1: Overall Pre-test scores for Experimental and control groups before treatment

Of Gene concept	Frequency(N=240)		Percentages (%)	
	Right	Wrong	Right	Wrong
Allele	88	152	36.7	63.3
Gene	129	111	53.8	46.2
Genotype	110	130	45.8	54.2
Phenotype	105	135	43.8	57.2
Homozygous	87	153	36.3	63.7
Heterozygous	83	157	34.6	65.4
Dominant allele	72	168	30	70
Recessive allele	66	174	27.5	72.5
Cross over	14	226	5.8	94.2
Linkage	15	225	6.3	93.7
Mendelian law	39	201	16.3	83.7
F1-generation	113	127	47.1	52.9
F2-generation	115	125	47.9	52.1
Phenotypic ratio	68	172	28.3	71.6
Genotypic ratio	63	177	26.3	73.7
Sex determination	103	137	42.9	57.1
Chromosomes/allele	112	128	46.6	53.4
Sex chromosomes	58	182	24.2	75.8
Types of mutations	210	30	87.5	12.5
Causes of mutations	181	59	75.6	24.4
Gene mutations disorders	41	199	17.1	82.9
Sickle anaemia	72	168	30	70
Gene and chromosomal mutations	13	227	5.4	94.6
<i>Drosophila melanogaster</i>	26	214	10.8	89.2
Incomplete dominance	117	123	48.8	52.2
F1&2 ratio of incomplete dominance	118	122	49.9	50.1
Genetically modified organisms	23	217	9.6	90.4
Opinions of GMOS	14	226	5.8	94.2
AVERAGE	81	159	33.6	66.4

After the treatment the experimental group showed an improvement in the overall performance with a majority (87.5%) displaying a correct understanding of the sub concepts, while only 40% of the control group displayed such understanding (Table 2). While the majority of the students (over 60 %) in the experimental group displayed a high level of understanding of all the 28 sub concepts the contrary was the case for the students in the control group.

Table 2: Post-test scores for Experimental and control groups after treatment

Gene concept	Frequency(N) and Percentages (%) of post test scores			
	Experimental group (N=120)		Control group (N=120)	
	Right	Wrong	Right	Wrong
Allele	119 (99.2%)	1(0.8%)	88(73.3%)	32(26.7%)
Gene	102(85%)	18(15%)	61(50.8%)	59(49.2%)
Genotype	105(87.5%)	15(12.5%)	60(50%)	60(50%)
Phenotype	116(96.7%)	4(3.3%)	65(54.2%)	55(45.8%)
Homozygous	104(86.7%)	16(13.3%)	60(50%)	60(50%)
Heterozygous	104(86.7%)	16(13.3%)	59(49.2%)	61(50.8%)
Dominant allele	84(70%)	36(30%)	40(33.3%)	80(66.7%)
Recessive allele	78(65%)	42(35%)	38(31.7%)	82(68.3%)
Cross over	98(81.7%)	22(18.3%)	56(46.7%)	64(53.3%)
Linkage	96(80%)	24(20%)	45(37.5%)	75(62.5%)
Mendelian law	103(85.8%)	17(14.2%)	53(44.2%)	67(55.8%)
F1-generation	116(96.7%)	4(3.3%)	61(50.8%)	59(49.2%)
F2-generation	115(95.8%)	5(4.2%)	54(45%)	66(55%)
Phenotypic ratio	68(56.7%)	52(43.3%)	45(37.5%)	75(62.5%)
Genotypic ratio	112(93.3%)	8(6.7%)	31(25.8%)	89(74.2%)
Sex determination	68(56.7%)	52(43.3%)	45(37.5%)	75(62.5%)
Chromosomes/allele	112(93.3%)	8(6.7%)	31(25.8%)	89(74.2%)
Sex chromosomes	120(100%)	0(0%)	41(34.2%)	79(65.8%)
Types of mutations	120(100%)	0(0%)	48(40%)	72(60%)
Causes of mutations	119(99.2%)	1(6.8%)	41(34.2%)	79(65.8%)
Gene mutations disorders	120(100%)	0(0%)	59(49.2%)	61(50.8%)
Sickle anaemia	118(98.3%)	2(1.7%)	56(46.7%)	64(53.3%)
Gene and chromosomal mutations	82(68.3%)	38(31.7%)	59(49.2%)	61(50.8%)
<i>Drosophila melanogaster</i>	112(93.3%)	8(6.7%)	58(48.3%)	62(51.7%)
Incomplete dominance	82(68.3%)	38(31.7%)	21(17.5%)	99(82.5%)
F1&2 ratio of incomplete dominance	112(93.3%)	8(6.7%)	41(34.2%)	79(65.8%)
Genetically modified organisms	76(63.3%)	44(36.7%)	18(15%)	102(85%)
Opinions of GMOS	112(93.3%)	8(6.7%)	32(26.7%)	88(73.3%)
AVERAGE (%)	105(87.5%)	15(12.5%)	45(37.5%)	75(62.5%)

The students who participated in the experimental groups improved their knowledge regarding gene and allele, genotype and phenotype, heterozygous and homozygous, dominant and recessive allele, genetic crosses involving filial generations in determining phenotypic and genotypic ratios among others. However, most of the students in the control group did not show marked improvement in the understanding of some sub-concepts including definition of term allele and gene, genetic crosses for determining phenotypic and genotypic ratios, chromosomes and

alleles, sex chromosomes, dominant and recessive allele, sex linkage and inheritance of sex linked gene in both pretest and post test. For the case of sex linkage and inheritance of sex linked gene in *Drosophila melanogaster* the students were confused between phenotype and genotype, and were unable to distinguish between a pair of alleles and chromosomes. They still displayed lack of knowledge regarding incomplete dominance, gene and chromosomal mutations. Most students in control group still perceived *Drosophila melanogaster* as a human-being or plant as per their statements given in the gene concept achievement test. Some of the answers given were as follows: *Drosophila melanogaster* is a plant resistant to diseases and pests; this organism possesses so many seedlings and offspring. As per these statements sampled, the students were confused whether *Drosophila melanogaster* (common name fruit flies) is a plant or animal.

Impact of CBT on Students’ Learning of the Gene Concept

The impact of CBT on the learning of the gene concept was determined statistically by testing the following null hypotheses: Ho1: *Computer-based technology has no effect on student achievement scores in the learning of gene concept* and H02: *Computer-based technology does not affect students’ understanding of specific gene concept sub concept*. This necessitated the computation of means and standard deviations of pretest and post test scores for the students in the three categories of schools for both the experimental and control groups. The results were as presented in Tables 3 and 4.

Table 3: Comparison of mean scores and the standard deviations (S.D.) of the pre-test scores of the Experimental and Control groups on the GCAT and GCMCDT.

ITEM		Provincial Boys’		Provincial Girls'		District Mixed	
		Mean	SD	Mean	SD	Mean	SD
GCAT	Experimental Groups	25.5	13.0	33.7	13.0	25.5	14.7
	Control Groups	28.8	13.1	24.2	10.4	29.7	15.1
GCMCDT	Experimental Groups	43.3	8.7	43.4	15.6	42.0	14.8
	Control Groups	48.8	10.3	36.3	9.7	43.4	16.1

The mean and standard deviation values in Tables 3 and 4 were further subjected to statistical analysis of variance (ANOVA).The results of the analysis for the pretest scores were as summarized in Tables 5. The ANOVA test at 0.05 level of significance revealed no significant differences in students’ achievement capabilities between the experimental and control groups

(homogeneity). The F- values less than the critical value was indicative of the non existence of significant difference between the scores of the groups.

Table 4: Comparison of mean scores and the standard deviations (S.D.) of the post-test scores of the Experimental and Control groups on the GCAT and GCMCDT.

ITEM		Provincial Boys'		Provincial Girls'		District Mixed		MEAN GAIN
		Mean	SD	Mean	SD	Mean	SD	
GCAT Groups	Experimental	67.8	7.6	66.5	15.2	53.2	15.9	34.3
	Control Groups	30.4	13.8	33.4	9.9	36.9	13.3	6.0
GCMCDT	Experimental Groups	78.1	6.8	72.3	11.3	65.7	12.1	29.1
	Control Groups	48.7	8.7	43.7	7.7	49.9	14.6	4.8

Table 5: Analysis of Variance of the Pre-test scores on the GCAT and GCMCDT.

ITEM	GROUPS	F-RATIO	CRITICAL VALUE
GCAT	Experimental	1.65	1.98(ns)
GCAT	Control	1.64	1.98(ns)
GCMCDT	Experimental	0.92	1.98 (ns)
GCMCDT	Control	0.10	1.98(ns)

ns- Not significant at $p < 0.05$ level.

The t-test was then performed on post test scores for the experimental and control groups. The results were as presented in Table 6. The application of a t-test reveals a significant difference between the experimental and control group with reference to use of CBT ($t_{cal}=4.33$, $t_{critical}=1.658$ **: $p < 0.05$) for experimental group whereas control group ($t_{cal}=1.48$, $t_{critical}=1.289$ *: $p < 0.1$). From the results shown under this table, the mean 72.03 and 62.49 of the of the two test items (GCMCDT and GCAT) respectively for the experimental groups is compared with the mean 47.44 and 37.03 for the control groups. The difference between the two means is 24.59 and 25.46. At 95% confidence level interval, hypothesis test results in a P-value (*: $p < 0.1$ **: $p < 0.05$), statistically, there is a significant difference between the two means. The t calculated values are greater than t critical values and these leads to the rejection of the null hypotheses. Based on t calculated values, therefore Computer-based technology (CBT) has an effect on student achievement scores and affects students' understanding of specific gene concept sub concepts.

Table 6: ANOVA results of the scores of post-test of the two groups

Group	N	Mean		t-values		p
		GCMCDT	GCAT	t-calculated	t-critical	
Experimental	120	72.03	62.49 (11.59)	4.33	1.658	**
Control	120	47.44	37.03 (11.2)	1.48	1.289	*

*a: Numbers in () are standard deviations *: p<0.1 **: p<0.05*

DISCUSSION

After the experimental group was exposed to computer-based simulation the students in the group showed greater improvement in performance as compared to those in the control group. These findings show existence of significant differences in achievement mean scores between the control and the experimental groups. The experimental groups exhibited a higher rate of achievement than the control groups. Several authors have established that the conventional methods of instruction have been cited as contributing to poor learning and consequently poor performance of students in examinations (Konana, 1995; Mbuthia, 1996; Too, 1996). Other researchers who supported them were Pelgrum and Plomp (1993) who went further to posit that computers can be used to improve both the instructional process by teachers and learning outcomes of the learners.

On the basis of these findings, it is can be inferred that the integration of CBT in the teaching and learning of the gene concept can indeed result in a positive effect on the students' level of general learning. This is in agreement with several studies on the efficiency of the use of CBI in recent years which have continued to show positive effects on learners' achievement, attitude towards computers and the subject matter, and perceptions of classroom environments (Kiboss 1997). Many studies carried out by several other authors have shown that computer simulations experiments are equally successful or more effective than real experiments in increasing understanding and promoting interactive learning in subjects ranging from Geography to Medicine (Cavender and Rutter, 1997; Coleman, 1994; Dewhurst, 1994; Dobson, 1995). Past research has shown that using computers for performing graphical functions seem to aid students' understanding of mathematics concepts and removes the drudgery of creating the physical graph (Mokros and Tinker, 1987). Therefore, CBT could be used to simulate experiments that are difficult to teach and

learn through traditional methods. These could be the basis of students' difficulties associated with concept formation and application of acquired knowledge in exercises (Pendley et.al, 1994, Lee and Pensham, 1996). These findings provide empirical evidence and basis for concluding that the use of computer based technology (CBT) instructional medium such as computer simulation experiments, facilitates the learning of higher level cognitive demand content such as the gene concept in the area of genetics.

CONCLUSIONS AND RECOMMENDATIONS

Several conclusions are made from the findings of this study. Firstly, it is apparent that poor performance and students' loss of interest in biology, particularly the gene concept in genetics, is a result of inadequate understanding of the concept. This could be attributed to the high cognitive demand of the concept and inadequate insightful teaching methods employed by the biology teachers. In essence, the internalization of the gene concept is of great importance to the cognitive development and for the proper acquisition of scientific taxonomies and a full understanding of the genetic principles. Secondly, an understanding of the central concept in biology acts as a mental tool of scientific thinking to communicate the scientific information intelligibly and thus facilitate the learning of related sub concepts. This is supported by the constructive theory of learning. Thirdly, the integration of CBT to the teaching and learning of the gene concept would revolutionise the teaching of biology in the curriculum. This is attributed to the affordances provided by the computer programmes and the need to use scaffolds to support students who use computers to learn new and intellectually challenging content such as the gene concept.

It is therefore recommended that schools should embrace use of computer and ICT in the teaching and learning of biology to offer new emerging learning environments in the education systems. Also, the ministry of education should put in place mechanisms regarding the use of ICT in each secondary school including offering computer-based technology services to science teachers alongside laboratories. In addition, schools should employ computer technicians with sound practical skills in the maintenance, troubleshooting and upgrading of computer systems and applications software.

REFERENCES

- Cavender, J.F. and Rutter, S. M., (1997). Multimedia: bringing the sciences to life: experiences with multimedia in the life sciences Association of Small Computer Users in Education (ASCUE) *Summer Conference Proceedings*, North Myrtle Beach, SC.
- Coleman, I. P., (1994). A computer simulation for learning about the physiological response to. *Advances in Physiology Education*, 11(1), 2–9.
- Dewhurst, D. G. A. O., (1994). Comparison of a computer simulation program and a traditional laboratory practical class for teaching the principles of intestinal absorption. *Advances in Physiology Education*, 12(1), 95–104.
- Dobson, E. L. A .O., (1995). An evaluation of the student response to electronics teaching using a CAL package. *Computers and Education*, 25(1–2), 13–20.
- Dreyfus, T. and Halevi, T. (1991). ‘QuadFun - A case study of pupil computer interaction’, *Journal of Computers in Mathematics and Science Teaching*, 10(2), 43–48.
- Entwistle, N.J., (1998). Approaches to learning and forms of understanding in B. Dart and G. Boulton-Lewis (Eds.), *Teaching and learning in higher Education* (pp.72-101). Melbourne: Australia Council for Educational Research.
- Goos, M. I., Galbraith, P., Renshan, P. and Geiger, V. (2003). Perspectives on technology mediated learning in secondary school Mathematics classrooms. *The Journal of Mathematical Behavior*, 22(1), 73–89
- Hoyles, C. and Noss, R. (1992). A pedagogy for mathematical micro-worlds. *Educational Studies in Mathematics*, 23(1), 31–57.
- Hounshell, P. B. and Hill, S. R., (1989). The Microcomputer and achievement and attitudes in High school Biology. *Journal of Research in Science Teaching*, 26(6), 543–549.
- Kesidou, S. and Roseman, S. E., (2002). How well middle school sciences do programs measure Up? Findings from projects2061’s curriculum Review. *Journal of Research in Science Teaching*, 39(6), 522–549.
- Kiboss, J. K., (1997). Relative Effects of a Computer-Based Instruction in Physics on Students’ Attitudes, Motivation and Understanding about Measurement and Perceptions of Classroom

- Environment. Unpublished PhD Thesis, University of the Western Cape.
- Kenya National Examinations Council reports, (2003-2008). *2002-2007 KCSE Examination Reports*. Nairobi-Kenya.
- Konana, L. S., (1995). Education, Science and Technology. Paper to Pan African Colloquim, Moi University, 21st February 1995.
- Lee, K.W. L., and Pensham, P. F., (1996). A general strategy for solving high school electrochemistry problems. *International Journal of Science Education*, 18(3), 543–555.
- Mbuthia, F. K., (1996). A Comparative Study of the Effects of Two Instructional Approaches on Student Performance in Kiswahili Poetry in Selected Secondary Schools in Eldoret municipality. Unpublished masters Thesis, Moi University.
- Michel, R. G., Calvari, J. M., Znamenskaia, E., Yang, K. X., Sun, T. and Bent, G., (1999). ‘Digital video clips for improved pedagogy and illustration of scientific Research with video clips on atomic spectrometry’. *Spectrochimica Acta Part B-Atomic Spectroscopy*, 54(13), 1903–1918.
- Mugenda, M.O. and Mugenda, A.G., (2003). *Research Methods; Quantitative and Qualitative Approaches*: Nairobi; African centre for Technology studies.
- Pendley, B. D., Bretz, R. L. and Norak, J. D., (1994). Concepts maps as a tool to assess learning in chemistry. *Journal of Chemistry*, 71(1), 9–15.
- Pelgrum, W. J. and Plomp, T., (1993). *The IEA studies of computers in education: implementation of an innovation*. Oxford: Pergamon press.
- SMASSE Report, (2000). *Manual for National in-service Education and Training for Biology Teachers*. SMASSE INSET.
- Too, J. K., (1996). A Survey of the Availability and Use of Media Resources in Mathematics Instruction: The Case of Secondary Schools in Nandi District, Kenya. Unpublished Masters Thesis, Moi University.

APPENDIX A:

GENE CONCEPT ACHIEVEMENT TEST FOR FORM IV STUDENTS

Dear student,

The purpose of this Gene Concept Achievement Test (GCAT) is to gather information on integration of computer –based technology in teaching and learning of gene concept in secondary schools in Western Province, Kenya.

Thank you in advance for your cooperation.

Q1.(a) Explain the differences between each of the following pair of terms:

- i) Gene and Allele
- ii) Genotype and Phenotype
- iii) Homozygote and Heterozygote
- iv) Dominant allele and Recessive allele
- v) Cross-over and linkage

b) The diagram below represent Mendelian observation made from a laboratory experiment showing inheritance of alleles from parent to offspring during the process of sex cell formation. Use it to answer the following questions.

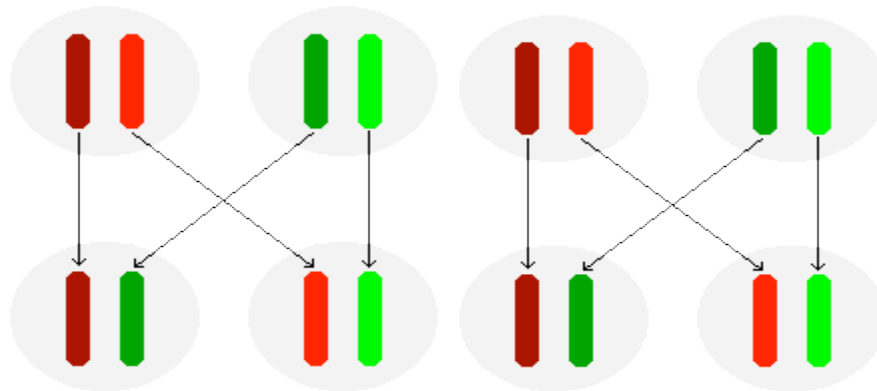


Fig3.Segregation of alleles in the production of sex cells.

Source:[Http://www.angelfire.com/dc/apgenetics/basics-principles,htm#Alleles#Alleles](http://www.angelfire.com/dc/apgenetics/basics-principles.htm#Alleles#Alleles)

- i) State Mendel's first law of inheritance.
- ii) Explain this law.

Q2. A scientist crossed a yellow flowered *Mirabilis sp.* plant with a green flowered *Mirabilis sp.* plant. He observed an F1 generation that had yellow flowers. He self-pollinated the F1 generation plants and got 1600 plants in the F2 generation.

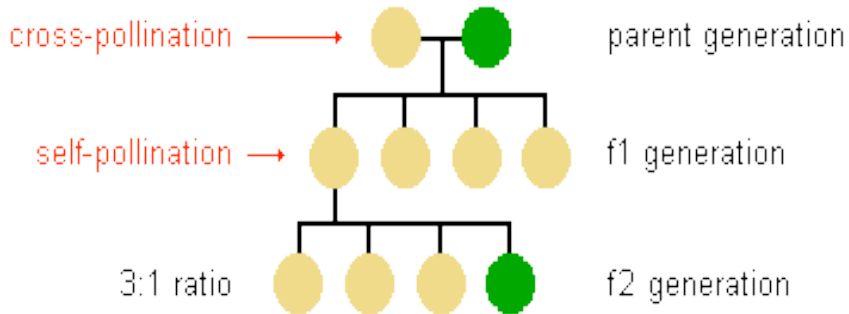


Fig 4. Cross pollination in a *Mirabilis sp.* plant.

Source: [Http://www.angelfire.com/dc/apgenetics/basics-principles.htm#Alleles#Alleles](http://www.angelfire.com/dc/apgenetics/basics-principles.htm#Alleles#Alleles)

- a) From the cross, identify the;
 - i). Plant with dominant genes
 - ii). Plant with recessive genes
- b) i) Make across showing how the F1 generation was obtained
 - ii). Make across showing how the F2 generation was obtained
 - iii) Make across to show the probable phenotypes of the f2 generation
- c) Calculate the number of plants in the f2 generation with
 - i) Yellow flowers
 - ii) Green flowers

Q3. A scientist designed an experiment in the laboratory to determine the sex of fruit flies in the laboratory. The scientist used the features shown below to distinguish male fruit flies from female fruit flies. Use to answer the following questions.

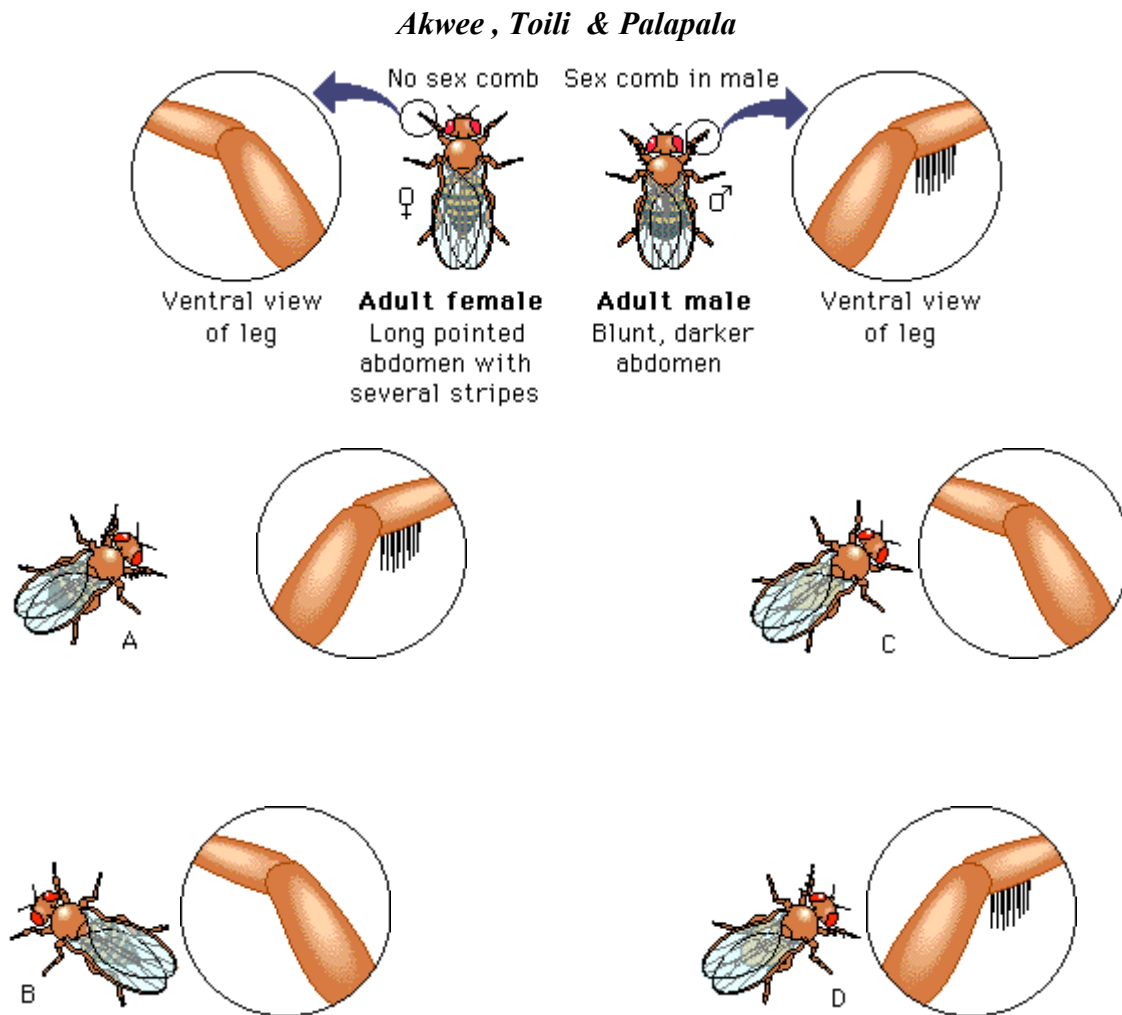


Fig 5. Sex determination in fruit flies.

a) i) Identify the fruit flies

ii) Between a pair of alleles and a pair of chromosomes, what determines the sex of fruit fly?

iii). Distinguish between sex chromosomes and sex-linkage.

iv). How is sex determined in human beings?

b) Later on, some mutations were seen in a breeding experiment in the laboratory of sex fruit fly as shown below.

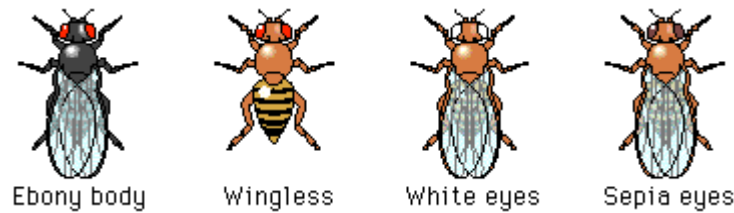


Fig 6. Common mutation in sex fruit flies

- i) State two types of mutations.
 - ii) Give examples of genetic disorders brought about by mutations.
- c) Sickle-cell anaemia is a hereditary disease due to a recessive gene which changes normal Haemoglobin (Hb-A) to abnormal Haemoglobin (Hb-S). The red blood cells of people with sickle-cell anaemia are sickle-shaped.
- i) What are the possible phenotypes of the offspring of a man who is heterozygous and a woman who is also heterozygous?
 - ii) What proportion of the offspring would have sickle-cell anaemia and sickle-cell trait?
 - iii) What is the genetic cause of sickle cell anemia?
 - iv) What are four uses of genetic engineering in the field of medicine and agriculture?
- d) i) State three causes of mutations in organisms.
- ii) Differentiate between point mutations and chromosomal aberrations
 - iii) The human somatic (body) cell has 46 chromosomes in its nucleus. How many of these are sex chromosomes?
- e) Most of genetic experiments in the laboratory, *Drosophila melanogaster* has been the most suitable for scientists. Give reasons why it is the most preferred fruit fly.

4. In the 'four o'clock' plant, red flower color (gene represented by R) shares equal dominance (co-dominant) with white flower (gene represented by W), the heterozygous plants being pink flowered. If a red flowered plant is crossed a white flowered one, what will be the flower color of:

- a) The F1 generation?
- b) The F2 generation after selfing F1?
- c) The offspring of a cross between the F1 and their red flowered parents?
- d) The offspring of a cross between the F1 and their white flowered parents?
- e) i) What do you understand by genetic modified organisms?
ii) What is your opinion regarding genetically modified foods in our country

Source: Njoroge, N et al (2006) Longhorn Secondary Biology Form Four New Syllabus .Nairobi-Kenya: Longhorn Publishers

APPENDIX B

B: GENE CONCEPT MULTIPLE –CHOICE DIAGNOSTIC TEST (GCMCDT)

1. What is the name given to chromosomes with the same shape, size; structure and it contain the same genes in the same locations.
A. heterozygous B. homozygous C. dominant D.homologous
2. Which one of the following refers to the location of genes in the same chromosomes and linked genes are inherited together?
A. gene linkage B. sex-linked genes C. sex-linked characteristics D. crossing over
3. Which of these explanation best explain the significance of meiosis?
i).Source of variation
ii).maintains genetic constancy in organisms
iii).Crossing over resulting in variations
iv).Gamete formation
A. iv, ii, i B. iii, i, ii C. i, iii, iv D. iv, iii, ii
4. The traits controlled by a gene located on the unpaired part of the X-chromosome are called :
A. Sex linked genes B. Crossing over C. Sex determination D. Sex-linked characteristics

Use this information to answer Q5-7

In a garden with plants of same pieces, 705 plants had red flowers while 224 had white flower

5. Work out the ratio of red to white flowered plants
A.1:3 B. 1.2:1 C. 4:0 D. 3:1

6. What is the genotypic ratio from the cross above?
A. 1:2:1 B. 3:1 C. 1:1 D. 2:2
7. Which type of inheritance is this?
A. Dihybrid B. Incomplete C. monohybrid D. complete
8. What is meant the term Allele?
A. The study of alternative different forms of genes for a specific trait
B. The segment of DNA coding for a particular proteins
C. Alternatives forms of the same gene.
D. Different forms of genes for specific traits
9. Homologous chromosomes not involved in sex determination.
A. 22nd pair XY
B. 23rd pair autosomes (AA)
C. 22nd pair autosomes (AA)
D. 44th pair XY
10. Name of scientist considered to be the father of modern genetics
A. Crick B. Mendel C. Griffith D. Messelson
11. Which one of the following is NOT a disorder in humans caused by gene mutations?
A. Haemophilia B. Sickle cell anaemia C. Color blindness D. Down's syndrome
12. In mice the allele for black fur is dominant to the allele for brown fur. What percentage offspring would have brown fur from a cross between heterozygous black mice and brown mice?
A. 50% B. 25% C. 100% D. 75%
13. Which ONE of the following statements best describes chromosomal translocation mutations?
A. Occurs when chromatids break at two places
B. The chromatids rejoins the middle piece, rotates and joins in an inverted position
C. Occurs when a section of chromatids break off and becomes attached to another chromatid of another chromosome
D. occurs when chromatids break off, rotates and rejoins the middle piece of other chromatids.
14. Which ones of the following best explain process that occurs during anaphase of Mitosis?
i). Sister homologous chromosomes separate.
ii). Sister chromatids move to opposite poles.
iii). Sister chromosomes aligned at the equator

- iv). Sister chromatids separate.
- v). The number of chromosomes doubles.
- A. ii,iv,v B.i,ii,iv C.ii,iii,iv D.i,ii,v
15. Allele that cannot influence phenotypic characteristics in the presence of a dominant allele
- A. Heterozygote B.Homozygote C.Recessive D.Dominant
16. Choose terminologies that best describe the explanations given below in the right order.
- i). Units in a chromosome that determines a given characteristics.
- ii). Allele that show phenotypic characteristics in a heterozygous individual
- iii).chromosomal state of gamete cell.
- A.Diploid, gene,dominant
- B. Gene,diploid,phenotype
- C. Gene, phenotype,Recessive
- D.Gene,dominant and diploid

Use this information to answer Q17-18

A man with normal skin color got married to a woman with normal skin colour. They give birth to three children, one of them an albino.

17. What are the probable phenotypes of the children?
- A. Aa,aa & Aa B. AA,Aa & aa C. Aa & Aa D. Aa & AA
18. If one of the boys with normal skin color married a girl who is a carrier for the albino gene, what is the probability that their first child will have normal skin color?
- A. $\frac{1}{2}$ B $\frac{2}{3}$ C. $\frac{3}{4}$ D $\frac{1}{4}$