

Effect of Programmed Instruction on Academic Achievement in Radioactivity among Students in Kenyan High Schools

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Abstract: This study was prompted by the urgent need for effective technology-based strategies in the teaching and learning of abstract chemistry topics whose inadequacy has led to students' low achievement in the subject during in the annual Kenya Certificate of Secondary Education (KCSE) examinations. Focus was on Programmed Instruction, a computer-based way of teaching Chemistry, as an alternative to the conventional methods of instruction in the topic of Radioactivity. The study was carried out in Likuyani sub-county, Kakamega County, Kenya. The pretest posttest quasi-experimental research design was adopted as a model. The study sample consisted of 466 form four students and 16 Chemistry teachers. Purposive sampling was used to select participants from a target population of 2,000 students and 56 teachers. Instructional software was created, validated and used to teach students in the experimental groups, while those in the control groups were taught the same content of Radioactivity using conventional methods of instruction. Two achievement tests were used to collect raw data, one before and the other after intervention. Data were analyzed both descriptively (using mean, mean gain and standard deviation) and inferentially (using One-way Analysis of Variance) at 0.05 alpha level of statistical significance. Results revealed that Programmed Instruction was more effective in improving students' achievement in radioactivity than the conventional instructional approaches [$F(5, 460) = 34.4, p < .001$ at $\alpha = .05$]. These findings will be of importance to Chemistry and Physics educators around the world, who have hitherto had problems with teaching abstract topics effectively for maximum achievement by their students.

Keywords: Programmed Instruction, Achievement, Radioactivity.

INTRODUCTION

Most countries around the world offer chemistry in their educational curricula so as to foster in their learners an interest in the scientific method of obtaining knowledge to help them become innovators and problem solvers. As a result, most countries, especially those in the developing world have continually channeled colossal amounts of their budgetary allocations towards technology-related discoveries. In Kenya for instance, this happens through the annual secondary schools science congress competitions, which rewards students who come up with innovations in technology geared towards providing immediate practical solutions to issues facing present day Kenya like renewable energy [1, 2].

The quest for this objective as however been met by several challenges. In Kenya, the greatest problem currently facing Chemistry education is poor performance by students in the subject during national examinations. This predicament has continually troubled the Kenyan education sector from as far as 10 years ago [1]. Use of conventional instructional strategies has been given as one of the reasons leading

to this situation [3]. Research reveals that the conventional methods of instruction are not the most appropriate for ensuring maximum achievement by students because (i) they encourage rote learning, (ii) learners remain passive in the most part of a lesson, (iii) it learners' individual differences are not effectively catered for and (iv) leads to minimum academic achievement by students especially in abstract concepts [4].

Radioactivity is regarded as one of the topics in the Kenya secondary schools chemistry curriculum in which students experience some challenges in understanding its concepts because it is abstract in nature [2]. The curriculum states that by the end of this topic, the learner should be able to (i) define radioactivity, half-life, radioisotopes and nuclides, (ii) state the different types of radioactivity, (iii) name the particles emitted during radioactive decay and state their properties, (iv) carry out simple calculations involving half-life, (v) write balanced nuclear equations, (vi) distinguish between nuclear fusion and nuclear fission and (vii) state uses of some radioisotopes and dangers associated with radioactivity

[5]. Most of these concepts are abstract in nature, which makes the conventional methods of instruction inappropriate for teaching this topic. The relevant question at this juncture is, “which instructional method is most effective?”

Programmed instruction (PI) is an approach to teaching and learning in which content is sub-divided into small parts in sequential order, whereby the student must be successful in one part before he or she can proceed to the next [6]. Research reveals that PI materials represent a viable alternative for average and below average students, who do not respond adequately to conventional approaches to learning [7]. PI was invented by B.F. Skinner and is based on his theory of verbal behaviour as a means to accelerate and increase conventional teaching. It typically consists of self-teaching with aid of a specialized textbook or teaching machine that presents material structured in a logical and empirically developed sequence or sequences. PI may be presented by a teacher as well. It has been argued that the principles of PI can improve classic lectures and textbooks. PI allows students to progress through a unit of study at their own rate, checking their own answers and advancing only after answering correctly [8, 9].

Computer software as was used this study can also be used to present content in small chunks called ‘frames’ on the computer screen. The Programmed Learning software that was used by students in the experimental groups of this study was developed by the researcher, with help from a software engineer. Before being used, the software was validated using experts from the Kenya Institute of Curriculum Development (KICD), who gave it a clean bill of health. The software was installed on all computers in schools that were assigned to the experimental groups, and was used for teaching and learning of the radioactivity. Content in the topic was placed on 15 frames, in sequential order, such that a student had to correctly answer a question at the tail end of a subtopic before the “proceed to the next” button on the computer screen could become active. Students who could not get correct answers were referred by the programme to a subsidiary frame, which had more examples and explanations in simpler language. The role of Chemistry teachers was to introduce the topic using conventional instructional methods and to summarize the topic when students were through with all the content. Teachers also helped students who had difficulty using the software during initial stages of the topic [1].

Statement of the Problem

The quest for an appropriate student-centred instructional approach in abstract Chemistry topics can no longer be over-emphasized. This is because in Kenya, secondary school students continue to perform

poorly in the Kenya Certificate of Secondary Education (KCSE), which has attracted the concern of many stakeholders, particularly because of the spill-over effects that dismal performance in Chemistry brings about as the knowledge of Chemistry facilitates learning of several other subjects like Biology, Physics and Agriculture [8, 10]. Among the factors that have been attributed to this problem is widespread use of teacher-centered instructional approaches, especially in abstract topics [11]. Most teachers use the conventional methods of instruction, despite them being known to be largely teacher-centred [12, 13]. To teach radioactivity effectively, form two Chemistry teachers should therefore rise to occasion and seize any available opportunity for students to learn and technically manage instruction by maximising the use of methods that allow students to use hands, eyes, ears and the mind to enhance effective learning.

Programmed Instruction is a perfect example of a student-centred instructional approach in the sense that (i) content is delivered in small chunks in logical sequence and (ii) the learners have to type answers by themselves using the computer keyboard, listen to audio-clipped explanations and also watch video-clipped examples on top of the teachers’ explanations, which keeps them actively involved in the lesson, diminishing any chance for distraction [6]. Even with these and many other advantages of PI, research on its effectiveness in the teaching and learning of the abstract topic of radioactivity has not been done in Kenya so far. Research on the effect of PI on Kenyan students’ achievement in the radioactivity was therefore long overdue, hence the study.

The specific objective of this study was to find out if there is any difference in achievement between students who are taught radioactivity using Programmed Instruction and those who are taught using the Conventional Methods of Instruction. The null hypothesis (H_0) formulated from the study’s specific objective was, “There is no difference in achievement between students who are taught radioactivity using Programmed Instruction and those who are taught using the Conventional Methods of Instruction.” This hypothesis was statistically tested at 0.05 alpha level of significance.

LITERATURE REVIEW

Achievement is defined as the learner’s level of successful understanding of concepts taught or learnt [8]. High achievement is the wish of all stakeholders in the education sector; hence research on any factor that affects students’ academic achievement is and will always be of interest to all stakeholders in the education sector. This section highlights on what previous studies have revealed, with regard to using programmed

instruction in education, and its effect on learners' academic achievement.

A study by Iserameiya and Anyasi, [14] in Nigeria, on the effect of programmed instruction on students' academic achievement in introductory technology revealed that the use of programmed instruction was more effective on students' academic performance than other methods. The study further noted that programmed instruction helps learners to be creative, develop new learning ideas and skills independently and also promotes active participation of the learner.

Another study by Kullik and Kullik [15], a meta-analysis indicated that classes which received programmed instruction had better examination scores than those in the CMI groups. One of the conclusions of their study was that traditionally, programmed instruction software was developed to employ the computers' capability to deliver individualized instruction. However, for economic reasons e.g. the need to provide a computer for every student and the problem of very few computers for classroom use, made software developers and teachers in third world countries to explore other avenues through which computer based learning might be amicably implemented in an environment with limited number of computers.

Meta-analytical reviews on co-operative programmed instruction [16-18] reported that programmed instruction resulted in better performance or higher scores in achievement tests. All these studies tend to agree that computer based co-operative learning method in heterogeneous groups (Mixed-high and low ability students) can improve the achievement of low ability students without significant reduction in the achievement of high ability students.

Rysavy and Sales [19] conducted a meta-analytic review of programmed instruction environments and found that discussions and joint actions taken by students tend to affect both what they do and how they learn. It was found that students tend to work faster and able to use factual information and learnt to answer problem-solving questions. This, they explained, supports the notion that when students learn, they interact not only with the teacher and subject matter, but also with one another.

A more recent study by Alaba *et al.* [20], on the effects of computer-assisted programmed instruction on Nigerian students' learning outcomes in typewriting revealed that the use of programmed instruction improves learners' achievement scores in typewriting examinations. The study further noted that about 97.6% of the students that were interviewed in the

study agreed that programmed instruction's mode of feedback improved their understanding in typewriting because they had the opportunity to repeat given tasks until satisfactory attempt was made.

MATERIALS AND METHODS

Research Design

This study adopted a quasi-experimental research design using the pre-test and post-test with control group as a model. The design was chosen because the units of sampling i.e. form four classes were already constituted and therefore it was unethical to re-constitute others randomly. The design however involved random assignment of intact classes to four groups labelled E1, E2, E3, C1, C2 and C3. All groups received both pre-test and post-test. E1, E2 and E3 were the experimental groups, and were taught radioactivity using programmed instruction while C1, C2 and C3 were the control groups, and were taught using the conventional methods of instruction. Pretesting was done to establish whether the groups had the same entry behaviour while post testing was done to determine the effect of intervention on students' achievement.

This design controlled for all major threats to internal validity. To control for interaction, different schools were assigned into experimental and control groups. Selection was dealt with by using intact streams [21]. No major event was experienced in any of the sampled schools that would have resulted in interaction between history and selection. The conditions under which the instrument was administered were kept as similar as possible in all the schools to control for interaction between selection and instrumentation [22].

Sample Size and Sampling Procedures

Purposive sampling was used to select four co-educational (mixed) secondary schools in Likuyani sub county, Kakamega County in Kenya, which offer computer studies as an examinable subject. This was because the instructional software developed for this study required many computers, whose sufficient number could only be found in such schools. Only co-educational schools were used so as to control for gender as an intervening variable. Likuyani Sub County was chosen for earlier mentioned reasons. Only form four students from each of the six sampled schools were included in the study sample because the topic under investigation - radioactivity is taught at this level the Kenyan secondary school Chemistry curriculum. A total of 466 students and 16 Chemistry teachers participated in the study. This sample size was arrived at basing on the formula of Krejcie and Morgan [27]. It is noteworthy that due to the already constituted form two classes, the four sampled groups were not equal in size i.e. E1=80, E2=75, E3=68, C1=72, C2=79 and C3=92.

Instrumentation

Raw data was collected using the Students' Entry Behaviour Determination Achievement Test (SEBDAT) as pre-test and the Radioactivity Achievement Test (RAT) as post-test. Both were one-hour achievement tests, whose items were set using a test specification grid, basing on all the six levels in the Bloom's cognitive domain of objectives [26]. The questions were weighted using the Kenya National Examinations Council's criteria of Low level > Middle level > High level in ratio 60:30:10 respectively. The purpose of the SEBDAT was to determine whether the sampled students had the same Chemistry achievement entry behaviour while the RAT served to determine the students' achievement in the topic of radioactivity after intervention. Questions in the SEBDAT came from across the form four syllabus while those in the RAT covered only the topic of radioactivity. The two tests were validated using two experienced examiners of Chemistry, who were asked to moderate them, checking for any faulty items. Defective items were paraphrased, modified and/or replaced, whichever was more appropriate, before use in the actual study.

Reliability of both instruments was verified using the split-half method, where the students' scores in both tests were split into two sets, then correlated. Cronbach's alpha coefficients of 0.773 and 0.804 were obtained for the SEBDAT and RAT respectively, which implies that these instruments, if used again would produce similar results as the co-efficients were above the threshold of 0.7, stipulated by George and Mallery, [23] as the rule of the thumb.

Data Collection and Analysis Procedures

All the research groups were given the SEBDAT, followed by intervention that lasted for 10 days. The RAT was thereafter administered to all the sampled students. The completed answer sheets were coded and the scores fed into SPSS version 21 for further analysis. The data was first analyzed descriptively by computing the achievement mean scores, mean gains and standard deviations for each of

the six research groups. The null hypothesis of this study was then tested inferentially using the independent samples t-test and one-way Analysis Of Variance (ANOVA) for pre-test and post-test administrations respectively. Both analyses were done at $\alpha=0.05$, to determine if the achievement mean scores of the groups under comparison differed significantly from each other in terms of academic achievement in chemistry both before and after intervention. One-way ANOVA was used because there were more than two groups in the post-test, classified basing on only one factor (group type), hence the choice of one-way ANOVA. Independent samples t-test was used because in the pre-test, there were only two groups being compared, experimental as one group and control as the other. Both groups were not related in any way, making independent t-test the most ideal choice and not any other type of t-test. Assumptions of these two parametric tests were assessed beforehand; normality of the achievement scores was assessed using the Shapiro-Wilk test, while homogeneity of variances of the achievement scores was assessed using the Levene's test [24, 25]. Both tests yielded non-significant p-values. This implied that data collected by the SEBDAT was fit for analysis, using parametric tests, without any possibility of committing type one and or type two statistical errors. Parametric tests also demand that the research groups used should be independent of each other. This important assumption was deliberately not assessed, because it had already been taken care of by the research design in the sense that only intact classes were selected and used for the study, for earlier explained reasons. Different schools were used as experimental and control groups also for this reason. None of the form four students in the research area therefore stood the possibility of being in more than one research group at the same time as the treatment in all groups was carried out concurrently.

RESULTS

Results of descriptive analysis of the sampled students' achievement before and after intervention were as presented in Table 1.

Table 1: Descriptive Analysis of Students' Achievement

GROUP	PRE-TEST		POST-TEST		MEAN GAIN
	MEAN	STD. DEV.	MEAN	STD. DEV.	
E1 (N=80)	42.85	6.745	52.91	7.671	10.06
E2 (N=75)	44.47	6.787	53.04	5.174	8.570
E3 (N=68)	43.34	5.962	52.77	5.355	9.430
C1 (N=72)	43.69	7.554	44.87	8.805	1.180
C2 (N=79)	42.94	8.009	43.81	6.934	0.870
C3 (N=92)	44.03	6.349	44.89	6.764	0.860
WHOLE GROUP (N=466)	43.55	6.909	48.72	8.39	5.120

A critical examination of Table 1 shows that while the achievement mean score of the entire sample

was 43.55 in the pre-test, group E2 had the highest mean of 44.5, while group E1 had the lowest mean of

42.9 marks. It can be deduced from this Table that the range between the highest and lowest mean score was 1.62 marks in the pre-test achievement mean scores. In the post test however, it can further be deduced that while the mean score for the entire sample was 48.72, group E2 had the highest mean of 53.0 while group C2 had the lowest mean of 43.8, a larger margin of 9.23 when compared to the pre-test statistics. It can also be pointed out from this Table that all experimental groups obtained mean scores that were higher than the sample mean, while the control groups obtained mean scores lower than the sample mean. We can also see from the

Table that even though all the groups had a positive deviation in their achievement mean scores, the experimental groups had higher mean gains than the control groups.

To determine whether or not the observed differences in achievement scores at the initial stage of the quasi experiment were statistically significant or not, independent samples t-test was used to compare the pre-test mean scores of the treatment and control groups, whose results were as shown in Table 2.

Table-2: Independent Samples t-test (2 tailed) on Pre-test Achievement Scores

		Levene's Test for Equality of Variances				
		F	Sig.	T	Df	Sig.
Score	Equal variances assumed	4.32	.198	7.63	465	.121
	Equal variances not assumed			7.63	465	.121

The Table shows that Levene's test for equality of variances yielded a non-significant f-value [F = 4.32, p = .198 at $\alpha = .05$], which implies that the variances in the pre-test achievement scores between the control and experimental groups were homogenous. Parametric testing was therefore appropriate for analyzing the scores, going by this assumption of equal variances. As the Table further reveals, there was no statistically significant difference in pre-test achievement scores between students in the control groups and those in the experimental groups [t (465) = 7.63, p = .121 at $\alpha = .05$] since the p-value obtained is

greater than the set alpha level. This implies that the sampled students were statistically at the same entry level with respect to achievement in Chemistry prior to learning radioactivity.

To establish whether or not the students' achievement differed between the six groups after intervention, one-way ANOVA was performed on the students' post-test achievement scores as collected by the RAT. Results of this inferential test were as presented in Table 3.

Table 3: One-Way ANOVA on Students' Post-Test Achievement Scores

SOURCE	D.F	SS	MS	F	P
Between groups	5	8,226.107	1,645.221	34.44*	.000
Within groups	460	21,969.151	47.759		
Total	465	30,195.258	1692.98		

*Significant at $\alpha = 0.05$

The Table indicates that in the post-test, there was a statistically significant difference in the mean scores of the six groups under comparison [F (5, 460) = 34.4, p < .001 at $\alpha = .05$]. These statistics imply that at least one of the groups differed significantly from the

rest in mean score. To find out which group(s) caused the significant p-value, post hoc test was necessary, which was done using Tukey's LSD, and the results were as presented in Table 4

Table 4: LSD post hoc test p-values for post-test achievement scores

	E1	E2	E3	C1	C2	C3
E1		0.175	0.565	0.001*	0.010*	0.030*
E2	0.175		0.976	0.001*	0.006*	0.010*
E3	0.565	0.976		0.004*	0.009*	0.002*
C1	0.001*	0.001*	0.004*		0.522	0.743
C2	0.010*	0.006*	0.009*	0.522		0.121
C3	0.030*	0.010*	0.002*	0.743	0.121	

*significant at $\alpha = 0.05$

The Table reveals that the post test achievement mean scores of the experimental groups (E1, E2 and E3) did not significantly differ from each other, and so was the case with control groups (C1 C2 and C3). However, the Table points out that the mean scores of the control groups significantly differed from those of experimental groups in favour of the latter. This result, when interpreted together with that obtained from the earlier mentioned descriptive analyses clearly point out the fact that students in the experimental groups, who were taught radioactivity via programmed instruction were superior to their counterparts in the control groups, with regard to achievement after in radioactivity after intervention.

The null hypothesis (H_0) of this study as earlier mentioned was, "There is no difference in achievement between students who are taught radioactivity using Programmed Instruction and those who are taught using the Conventional Methods of Instruction". Inferential testing of this hypothesis however found a statistically significant f-ratio on the six post-test achievement mean scores and subsequent post hoc testing attested to the fact that students in the study's experimental groups had significantly higher achievement mean scores than their counterparts in the control groups. The null hypothesis was consequently rejected since the empirical evidence arising from both descriptive and inferential analyses of data collected in this study suggests the contrary.

DISCUSSION AND CONCLUSION

It was established that using programmed instruction in the topic of radioactivity improves achievement of students in the topic as compared to using the CMI. This was because students in the experimental groups of this study obtained significantly higher mean scores in the post test than their counterparts in the control groups, which was not the case in the pre-test. This drastic change in achievement is attributed by the researcher to treatment (teaching radioactivity using programmed instruction) that the experimental groups received because in the pre-test, the achievement mean scores of students in all the groups were statistically the same. These findings are absolutely in unison with those of Iserameiya and Anyasi, [14], whose Nigerian study found out that the use of Programmed Instruction, was effective on students' academic achievement and also promotes learners' active participation in a subject.

Another study by Alaba *et al*, [20] on the effects of computer-assisted programmed instruction on Nigerian students' learning outcomes in typewriting also concurs with the findings of this study as it revealed that 97.6% of the students that were interviewed in that study agreed that programmed instruction's mode of feedback improved their understanding in typewriting because they had the

opportunity to repeat given tasks until satisfactory attempt was made. On the basis of the data collected in this study and the empirical evidence provided by the study's findings, it can be concluded that the use of programmed instruction in the radioactivity significantly improves students' achievement in the topic and Chemistry as a subject compared to the conventional methods of instruction due to its student-centeredness. Teachers of Chemistry around the world, especially those in Kenya should therefore embrace it fully, especially in abstract topics so as to solve the current performance crisis plaguing Chemistry education.

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