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Hands-on Genetics and Pupils' Academic Achievement at Selected Secondary Schools in the Copperbelt Province of Zambia

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Abstract
Academic achievement of the majority of pupils has remained poor in genetics as observed from the grade 12 final examinations in most of the public senior secondary schools in Zambia. Pupils' underachievement in genetics has been attributed to several factors such as poor modes of teaching, absence of teaching and learning resources and the abstract nature of the said topic. A considerable number of science educators believe that the use of hands-on mode of teaching using physical materials would improve pupils' performance in genetics. Data to support this conception are limited in Zambia. It was against this backdrop that the current study was undertaken to establish one way or the other the effects of hands-on teaching of genetics on pupils' achievement in senior secondary school in Zambia. Four mixed-sex public senior secondary schools were considered from the Copperbelt province. Several hands-on activities were designed out of low cost physical materials and annotated diagrams which were used for this purpose. The study used the Solomon Four, Non-Equivalent Control Group Design. The two experimental groups were taught using the hands-on method and the two control groups were taught by using conventional modes of teaching. The said four groups were each selected by using simple random sampling. The sample size of the study was 146 pupils. In addition, four biology teachers took part in the study. In this study, Science Achievement Tests (SAT) in form of Multiple Choice Test (MCT) were used to collect the required data on pupils' achievement. The instruments were validated by experts from the department of Mathematics and Science Education. Pupils' scores were compared for pre-treatment and post intervention. Also, background information from pupils and teachers was collected using a questionnaire. The pre-test results were analyzed using Mann-Whitney U test while the post-test scores were analyzed by using Kruskal Wallis H test and Mann-Whitney test. All these statistical tests were determined with the aid of a statistical programme called Statistical Package for the Social Sciences (SPSS) version 16.0. Data collected from background questionnaires were analyzed by employing two sample t-test between percentages. The level of significance for the rejection of the hypotheses was set at 0.05 alpha level.The results of the study showed that there was a statistically significant difference between the means of the experimental groups and that of the control groups with an effect size (r^2) of .60. Pupils who were taught genetics by using hands-on teaching approach outperformed those who were taught the same concepts of genetics by use of conventional modes of teaching. The findings of the current study are likely to benefit biology teachers, educators and administrators of education in Zambia.
Keywords: Hands-on genetics, Hands-on activities, Academic achievement, Genetics

1. Introduction

Knowledge of genetics is critical in understanding other areas of biology. However, it has proved to be a challenging topic to learners, especially in secondary schools in Zambia. To address this challenge, this study was conducted to establish whether hands-on genetics enhance academic achievement among pupils in biology in the Copperbelt Province.

1.1 Background of the study

Genetics is considered as one of the most important disciplines in biological sciences. It is a fundamental part of biology which deals with, heredity and variation in living organisms. It also intersects frequently with other life sciences. For example, one needs to understand basic genetics in order to appreciate evolution. There are so many areas of genetics which are employed in the study of molecular biology. It is against this background that genetics contains unifying concepts essential for other disciplines in biology (Banet and Ayuso, 2000). In view of this, the knowledge of genetics can be said to play a very important role in the understanding of other areas of biology (Murray-Nseula, 2011). Genetics content, however, poses a challenge to both teachers and pupils to teach and learn respectively as seen from the school certificate results.

Pupils' underachievement in genetics has been noted in many parts of the world. For example, Dean-Paul and Kola (2008) study in Jamaica revealed that most candidates in the Caribbean Advanced Proficiency Examinations (CAPE) did not perform well in questions set on genetics. Similarly, the chief examiner's report of West African Examination Council (WAEC) also noted that over the years (WAEC, 2009; 2010; 2011 and 2012) senior secondary school candidates' results in their biology examinations was quite poor in genetics. This finding was consistent with that of Hambokoma and Kagamiyana (2007) who sought to determine the nature and causes of learning difficulties in genetics at Senior Secondary School level in Zambia. With respect to Zambia, a considerable number of chief examiner's reports of the Examination Council of Zambia, (ECZ) have shown that there is underachievement achievement in genetics (ECZ, 1992, 1997, 2005, 2009, 2010, 2011) in the country for some time now. The issue of pupils' underachievement in genetics is not only confined to developing countries but also in developed countries like the United Kingdom where the chief examiners' report of June 2013, by Edexcel of Pearson, indicated that most candidates confused the recessive disorder concerning sickle cell and cystic fibrosis.

While poor students' performance in genetics at secondary school level has been extensively studied in many parts of the world, there is little known on the 'development and field-testing' (Marie-Christine at el., 2005) of the modes of teaching that would improve students' achievement in genetics. Against this backdrop, the persistent pupils' underachievement in genetics noted in the chief examiners' reports of ECZ observed above and the research reports by Hambookoma et al (2002) and Hambookoma and Kagamiyana (2007) necessitated this study

1.2 Statement of the Problem
Biology teachers on the Copperbelt province of Zambia have been teaching genetics using traditional-based methods and pupils' performance in the subject has remained poor as shown by ECZ results over the years. Therefore, this study investigated the effects of hands-on based methods of teaching genetics on the pupils' academic achievement in genetics on the Copperbelt province of Zambia.

1.3 Purpose of the Study
The study sought to investigate the effects of hands-on mode of teaching genetics on pupils' academic achievement in genetics at senior secondary school level in the Copperbelt province.

1.4 Objective of the study
The objective of the study was to compare the mean achievement test scores in genetics of students taught genetics using the hands-on methods and those taught the same concepts of genetics using conventional-based teaching methods

1.5 Hypothesis of the study
The following null hypothesis guided the study and was tested at 0.05 confidence level of significance.
H_O: There is no significant difference in the mean achievement test scores in genetics of pupils taught using hands-on based methods and those taught the same concepts of genetics employing conventional-based methods.

2. Literature review
There is a paucity of knowledge on this topic in Zambia. Most literature shows the effect of hands-on science on students' achievement in science topics other than genetics.

The available literature indicates that hands-on methods of teaching actively engage learners in the learning process, physically and mentally, as they explore concepts underlying genetics. This implies that every hands-on activity is linked to a specific minds-on activity ((Miller and Abrahams, 2009). Whereas hands-on methodology largely focuses on visualization of concepts being taught, the traditional method of teaching genetics essentially involves teaching the subject theoretically. Literature reviewed also indicated that teaching genetics without the use of concrete objects is one of the causes of pupils' poor performance in genetics at secondary school level (Hambokoma et al., 2002; Haambokoma and Kagamiyana. 2007 and Topcu and Sahin-Pekmez 2009).

In hands-on genetics, learners specifically interact with the physical learning materials such as models, photographs and annotated drawings as they explore a given phenomenon. In other words, hands-on genetics affords pupils an opportunity to explore and apply the concept being learnt and relate it to real life situations. With respect to learner's exploration and engagement in the learning process through hands-on teaching, Agogo (2014) noted that pupils who were taught genetics using exploration and engagement in the hands-on activities developed more interest in genetics (as a topic) than those who were taught through the lecture method. Agogo (2014) employed only one source of data collection. As a result of this, one has to be cautious regarding the application of the result of this study.

Hoppe (2013) conducted a study which aimed to determine whether there was a correlation between the use of hands-on activities among other things and students' achievement in genetics. The concepts in genetics which were covered in this study included the following: alleles, trait, chromosome, Mendelian inheritance, Punnett square, sex determination, protein synthesis and DNA structure. In this study, the hands-on activities which were employed comprised of physical models which were manipulated by students during their learning process.

Another study which employed physical models to provide an opportunity for pupils to visualize abstract concepts was one carried out by Venville and Donovan (2008) of the University of Western Australia which sought to explore the way pupils of different age groups use a physical model to understand abstract concepts in genetics. The study found that the use of physical models during genetics lessons increased pupils' understanding of concepts in genetics. The study, however, observed that different physical models had different effect on the learners of different age group. The study claims that for the year two, the use of the said type of model provided pupils with a concrete image required for them to visualize the concept of inheritance. The study further claims that physical models helped year five pupils and some nine-year-old pupils to develop an association among the concepts of organisms, inheritance, genes and the concept of deoxyribonucleic acid (DNA). With respect to the 12-year-old pupils the study reported that physical models helped pupils in the stated age group to consolidate their conceptualization of concepts in genetics. The study under discussion seems to have the following implications for genetics education. The first implication is that physical models can be employed in teaching genetics across different age groups. The second implication is that a teacher should use suitable or appropriate physical model for a particular age group. The third implication is that a physical model has the potential to increase pupils' visualization of an abstract concept in genetics. Although the results of this study were positive regarding the effects of the physical model on the understanding of concepts in genetics, it is worth noting that the results of this study cannot be generalized beyond the site of the study. This is because the study adopted a case study methodology rather than the experimental-based. In view of this, one needs to be cautious when applying the findings of this study.

According to the Australian Academy of Science, AAS (2009) annotated drawings have been described as a visual representation meant to illustrate an idea, object, or concept in a teaching and learning situation. Keogh and Naylor (1996) further indicated that annotated drawings tend to increase students' visualization of concepts in genetics lessons. Similar findings were obtained by Danmole and Lameed (2014) and Danmole and Femi-Adeoye (2004). Annotation can, therefore, be employed by a teacher to help students observe structure and function of what has been drawn (Zywica and Gomez, 2012). According to Zywica and Gomez (2012) annotated drawing strategy employs diagrams and photographs to link structure and function. In this version of hands-on teaching strategy, students usually work individually to describe the process and then conceptualize what they have noted in the drawing on their own (Zywica and Gomez, 2012).

In conclusion, the available literature on the effects of hands-on genetics on pupils' academic achievement is mixed: Some literature shows that hands-on method of teaching genetics improved pupils' understanding of the subject. Some literature however, indicates that hands-on teaching of genetics had insignificant effect on pupils' conceptualization of genetics. This seems to raise a question: is hands-on teaching of genetics using physical materials misunderstood or misapplied by teachers? (Obsorne, 2015).

3. Conceptual Framework

The conceptual framework adopted for this study was derived from Ludwig's systems theory. It is based on the input-process-output system: The education model. In this model, education is seen as a productive system, in which products are transformed into outcomes (Juap (2004). According to Nooriafshar (2004) the teaching of genetics can be modeled as an input-process-output system. In hands-on teaching of genetics, input in the form of resources: physical objects and annotated drawings enter into the system. In the conventional-based teaching of genetics, input in form of lectures and lecture notes enter into the system. After teaching (the conversion process) an output in the form of pupils' achievement is realized. According to Nooriafshar (2004), the process phase may be cyclic involving the following: plan, organize, and feedback on the performance of the system. The diagram below depicts the conceptual framework employed in the study.

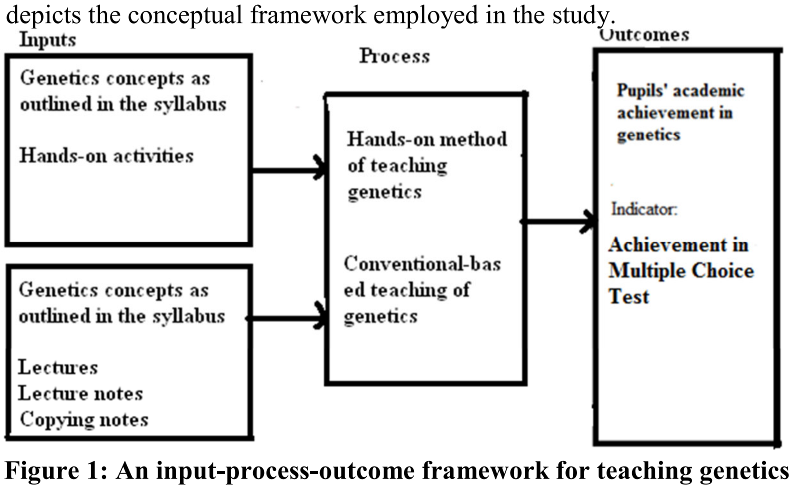

Figure 1: An input-process-outcome framework for teaching genetics
Source: Adapted from Knoontz and Weihrich (1988)

4. Methodology and Procedure

This section focuses on the methodology of the study. Specifically, it looks at the plan and methods that were used in the study.

4.1 Research Design

The study employed Solomon Four, Non–Equivalent Group Control Design. The design was chosen for this study over other designs because the sampled subjects for the present study came from intact biology classes. Intact biology classes were used in the study because school authorities in the Copperbelt Province could not allow the researcher to 'disrupt' the normal classes for the purpose of conducting a study (Fraenkel & Wallen, 2000). Secondly, unlike other designs, Solomon Four, Non–Equivalent Group Control Design was able to address the major threats to internal validity such as the testing threat to internal validity. According to William (2006) 'a testing threat occurs when the act of taking a test affects how people score on a re-test or posttest'. However, the Solomon Four Non-Equivalent Group Design does not specifically deal with threats to internal validity. This design had an advantage over other designs in terms of assessing the homogeneity of the study groups by applying independent sample t-test or Mann-Whitney U of the pre-test scores based on experimental group 1 (pretest experimental group, E1) and the control group 1 (pretest control group, C1) of the study before applying the intervention. It can therefore be noted that this design is able to address some of the difficulties plagued by the pretest-posttest designs. The table below shows the notation for Solomon Four, Non –Equivalent Group Design.

Table 1: Representation of Solomon Four Non-Equivalent Control Group Design

Groups	Pre-test	Treatment	Post-test
Pre-test Experimental Group (E1)	O1	X	O2
Pre-test Control Group (C1)	O3	-	O4
Unpre-test Experimental Group (E2)	…	X	O5
Unpre-test Control Group (C2)	…	-	O6

Adapted from Fraenkel and Wallen (2000)

In the table above, groups C1 and C2 represent mixed-sex public secondary schools that employed convention-based methods of teaching while groups E1 and E2 represent mixed-sex public secondary schools that were taught using hands-on methods of teaching genetics. With respect to the variables, they were defined such that O1 and O3 are pretest; O2, O4, O5 and O6 are the posttest. As for 'X', it represents the Experimental treatment, which involved the use of hands-on methods of teaching genetics. While a dash (-) entails no treatment was applied, the dotted lines (…) implies non-equivalent groups were employed in the design.

Prior to the commencement of the study, Groups C1 and E1 were pre-tested. After the application of the intervention, all the four groups of the study: namely, C1, C2, E1 and E2, were post tested.

The study employed a considerable number of hands-on activities which were essentially made out of low-cost physical materials. Specifically, physical models, annotated drawings, photographs and strips of paper depicting hereditary features such as chromosomes and genes. It is important to note that the hands-on activities used in the study were of different types with respect to the levels of biological organization, namely, population, organismic, cellular and molecular. The diagram shown below represents the sequence of teaching which was followed using hands-on teaching of genetics.

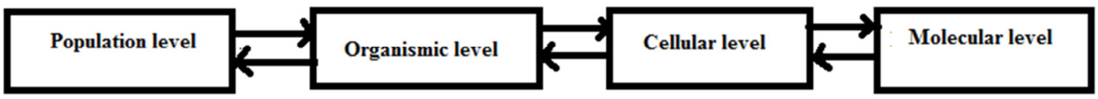

Figure 2: Sequence of teaching genetics employed in hands-on genetics
Adapted from Knippel (2002)

The arrows indicate that pupils had to move from one level to another level as they were engaged in interrelating concepts at different levels of the biological organization. The arrow pointing to the right indicates that pupils had to descend from that particular level to the next level (Knippel, 2002). Similarly, the arrow pointing to the left indicates that the pupil had to ascend from one level to the next. (Knippel, 2002).

As for the control groups, they were taught genetics mainly by 'chalk and talk'. Learner participation was limited to listening from the teacher. Tasks were theoretically covered. That is, pupils were not afforded an opportunity to have concrete experience with genetics concept being taught. That is, the control groups were taught genetics essentially without the use of hands-on activities.

4.2 Population and Sample of the Study

The target population of this study was grade 12 pupils from mixed-sex senior public secondary schools in the Copperbelt province of Zambia. The accessible population was 1 600 grade 12 pupils from four mixed-sex senior public secondary schools because genetics, the topic the study was interested in, is generally covered in

grade 12 specifically, in term three on the Copperbelt. Public senior secondary schools were chosen in favour of private secondary schools because the latter were comparable in terms of class size, age and learning facilities.
The sample size for the study was 155 pupils of whom 84 were boys and 71 were girls. The number of pupils who participated in the study according to the groups as per design of the study was as indicated in the table below.

Table 2: Number of Pupils who participated in the study according to experimental and control groups

Groups	C1	E1	C2	E2	Total
Number of pupils in each group	40	38	41	36	155

Source: From the Field

Each of the four sampled groups had at least 30 pupils. Since the number of pupils in each study group was more than 30, this sample had met the minimum number of participants required for the Solomon Four Non-Equivalent Control Group design (Mugenda and Mugenda, 1999).

4.3 Sampling Technique

Prior to the sampling exercise, Copperbelt province was divided into four zones so as to increase the possibility of having schools in the study sample reasonably far apart. This move was intended to reduce on the interaction of pupils in the experimental and control groups.

Upon 'zoning' of the province, simple random sampling was used to select one school from each zone. Four schools were selected because the design adopted for this study (the Solomon Four Non Equivalent Groups Design) requires four groups. Random sampling was suitable for this study because it ensured that all mixed-sex senior public secondary schools in each zone had equal chances of being chosen. The four randomly selected schools were yet again subjected to simple random sampling in order to choose two schools which served as experimental groups and other two schools which served as the control groups. This same sampling technique was again employed to select one class out of eight classes from each sampled school.

In this sampling technique, names of all mixed-sex senior public secondary schools in each zone were written on slips of paper and then put into a box. Thereafter, the slips in the box were mixed thoroughly well. Then, one slip was picked from the box and the name of the school written on it was then noted. The stated procedure was again performed to select a class from each sampled school.

4.4 Research Instruments

The study employed Genetics Achievement Tests in form of Multiple Choice Test MCT and Pupil Background Questionnaire. While MCT was used to assess pupils' academic achievement and their progress in learning genetics, the Pupil Background Questionnaire was used to collect pupils' information concerning their access to some educational resources: namely, computer, study table, biology textbooks, TV accessing biology lessons and internet access. It is important to note that MCT was chosen for this study because in Zambia student achievement in genetics is usually measured by the use of multiple choice items as the case in biology paper one at grade 12 examinations of the Examination Council of Zambia (ECZ). The MCT comprised of 30 multiple choice items. Each item had five alternative options to choose from. In order to reduce on guessing a minus mark was awarded for a wrong answer. The MCT was initially piloted in four mixed-sex public schools on the Copperbelt that were not sampled for the main study. In order to increase content validity of the MCT items, the test was scrutinized by biology education lecturers from the University of Zambia. Besides expert advice, peers in the Biology Education department of Mukuba University provided valuable advice as well which helped to improve the quality of the test.

4.5 Data Analysis

According to Gijsbert (1999) the statistical treatment of data obtained through the use of Solomon Four, Non-Equivalent Control Group Design is not straight forward. As a result of this, the researcher had to look at statistical methods which were employed in some studies which made use of the above stated research design. A case in point is a study conducted by Githun and Mwangi (2013).

Specifically, the present study employed the following statistical tools: the Mann Whitney U test, two sample t-test between percent and the Kruskal-Wallis H test. The Whitney U test was used to analyze the pre-test scores of C1 and E1 whereas the two sample t-test between percent was employed to determine whether the experimental and the control groups differed significantly in terms of their exposure to educational resources at their homes. As for the Kruskal-Wallis H test, it was used to analyze the post-test scores of all the four groups of the study.

5. Results of the Study

The results of the study are presented under the following sub-headings (1) the pre-test results, notably, the pupils' background knowledge in genetics prior to the intervention and pupils' access to the learning resources prior to the intervention. (2) The post-test results.

5.1 The Pre-test results

Prior to the analysis of the results of the pretest, the pre-test results were tested for normality and homogeneity. The pre-test scores did not meet one of the most critical assumptions of a parametric test, the assumption of normality. In view of this, a non-parametric statistical technique called Maan-Whitney U test was employed.

5.1.1 Pupils' background knowledge in genetics prior to the intervention

The SPSS version 16 was used to generate the Mann-Whitney U test output. The table below shows the results of Mann-Whitney U test for the pretest academic achievement scores in genetics of pupils in the control group, C1 and the experimental group, E1.

Table 3: Results of the Mann-Whitney U test to compare pre-test academic achievement scores of pupils in C1 and E1

	Test scores
Mann-Whitney U	789
Wilcoxon W	1650
Z	-0.296
Asymp. Sig. (2-tailed)	0.767

Table 3 reveals that the pre-test academic achievement scores of pupils in C1and E1 did not show statistical significant difference (Z = -0.296; P = 0.767> .05) between them. This implies that pupils in C1 and E1 had somewhat similar background knowledge in genetics. This implies that the groups were comparable and subsequently suitable for the study.

5.1.2 Pupils' access to the learning resources prior to the intervention

A two sample t-test between percent was performed prior to the commencement of the study in order to determine whether there was a statistically significant difference between the control group, C1 and the experimental group, E1 with respect to pupils' access to the educational resources; namely, the computer, study table, biology textbooks, TV accessing biology lessons and internet facility at their respective homes. prior to the commencement of the study. A statistics on-line calculator was employed to determine the two sample t-test between percent of pupils' pre-test academic achievement scores of C1 and E1.

Table 4: Results of the Two sample t-test between percent of C1 and E1

	Control group, C1		Experimental group, E1				
Item	**P1**	**S1**	**P2**	**S2**	**df**	**t-statistic**	**P value**
Computer	47.2	53	40	55	106	0.754	0.4522
Study desk (table)	54.7	53	69.1	55	106	1.542	0.1262
Biology textbooks	50.9	53	60	55	106	0.951	0.3436
TV accessing biology lessons	55.6	53	63.7	55	106	0.85	0.3928
Internet access	51.9	53	49.1	55	106	0.291	0.7717

Source: From the Field

Legend: P1 stands for percent of the control group
P2 stands for percent of the experimental group
S1 stands for sample size of the control group
S2 stands for sample size of the experimental group

The two sample t-test between percent for C1 and E1 was not significantly different for all the stated educational resources: computer, p = .4522 > .05; study desk (table), p = .1262 > .05; biology textbooks, p = .3436 > .05; TV accessing biology lessons, p = .3928 > .05 and Internet access, p = .7717 > .05. This means that pupils in the control group, C1 and the experimental group, E1 have similar access to the above stated educational resource prior to the intervention of the study.

5.2 The Post-test results

A non-parametric test known as Kruskal-Wallis test was employed in analysing the post-test academic achievement scores of the four groups of the study. Presented below are SPSS Statistics Output for the Kruskal-Wallis H Test. They include table showing descriptive statistics, table of results of mean ranks and table of results for test statistics of the said statistical technique.

The table below shows the descriptive statistics of Kruskal-Wallis test SPSS output on the post-test academic achievement scores of the four groups of the study.

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Table 5: Post-test mean scores obtained by pupils in their respective groups

Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
C1	40	53.1	12.9	2	49.2	57.4
C2	41	56.1	13.1	2	51.9	60.2
E1	38	83.5	8.6	1.4	80.6	86.3
E2	36	67.1	7.2	1.2	64.7	69.5
Total	155	64.6	16.1	1.3	62.1	67.2

Source: From the Field

In table 5, N represents number of pupils. Std stands for standard.

Table 5 shows that the experimental groups, E1 and E2, had higher mean post-test academic score than the control groups, C1 and C2. This implies that pupils who were taught genetics using hands-on mode of instruction had better post-test academic achievement scores than the two control groups of the study.

In order to compare the effects of the two different methods of teaching explored in this study, the mean ranks of post-test academic achievement scores of the four groups were determined. The table below provides the mean ranks of the post-test academic achievement scores of the four groups of the study.

Table 6: Results of Kruskal-Wallis test to compare the groups' post-test Mean Ranks

Groups		N	Mean Rank
Test scores	E1	38	130.8
	E2	36	84.8
	C1	40	47
	C2	41	53.3
	Total	155	

The table shows that pupils in the two experimental groups had higher posttest academic achievement scores compared to those in the two control groups of the study.

In order to establish whether the difference in pupils' posttest academic achievement scores in genetics (group by group) was statistically significant, the statistical significance or p value of Kruskal-Wallis statistical test was determined. Table …. below displays the p-value of the stated test on the posttest academic achievement scores of the four groups of the study.

Table 7: Results of Test Statistics[a,b] Kruskal-Wallis statistical test

	Test scores
Chi-Square	85.3
Df	3
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Groups

The above table shows that Kruskal-Wallis statistical test on the posttest academic achievement scores was statistically significant, ($p = .000 < .05$). This implies that the four groups were statistically different in their academic achievement in genetics.

In order to ascertain the size of the difference (effect size) of the intervention between the groups of the study an effect size of the Kruskal-Wallis test was determined. The table below displays an effect size of the Kruskal-Wallis test based on posttest academic achievement scores of the experimental and the control groups.

Table 8: Effect size of the Kruskal-Wallis test

	Eta	Eta Squared
Test scores * Group	.742	.60

Table 8 shows an effect size of the intervention as .60. This means that the magnitude of the difference between groups of the study had a medium effect on the teaching of genetics since it was between .2 and .8.

Overall, the Kruskal-Wallis test was significant, ($X^2(3, N = 155) = 85.3$, $p = .000 < .05$), with an effect size (r^2) = .60.

Comparisons between pairs of groups

Because the overall test was significant, the Mann-Whitney U test was run to compare results of the groups involved in the study. This statistical procedure was intended to locate the difference between pairs of groups. The table below displays the Mann-Whitney U test results between pairs of the groups of the study.

Table 9: Results of the Mann-Whitney U test between pairs of groups

	E1 and E2	E1 and C1	E1 and C2	E2 and C2	E2 and C1	C1 and C2
Mann-Whitney U	108	47.5	60	338	324.5	712.5
Wilcoxon W	774	867.5	921	1199	1144.5	1532.5
Z	-6.3	-7.1	-7.1	-4.1	-4.1	-1
P value	0.000	0.000	0.000	0.000	0.000	0.308

The table shows significant differences among the following pairs: E1 and E2, E1 and C1, E1 and C2, E2 and C2, and E2 and C1. This is because the p value for each of the stated pairs was less than .05. That is, p = .000 < .05 for each case. However, no significant difference was found between the control groups (C1 and C2). This is because the statistical significance of the Mann-Whitney U test was greater than .05, (p = .308 > .05).

How much Gain or Growth pupils made during the Intervention

To determine whether there was academic progress in terms of pupils' gain over the period of intervention, the pre-test mean scores and post-test mean scores of the control group, C1 and the experimental group, E1 were compared as shown in the table below.

Table 10: Paired samples statistics of pretest scores and posttest scores

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest scores	30.96	78	6.863	0.777
	Posttest scores	68.00	78	18.715	2.119

The table shows that pupils had a higher mean score in the posttest than they had in the pretest. This result implies that pupils performed much better academically in the posttest than in the pretest.

Finally, a paired sample t-test was run to establish whether there was a statistically significant difference in the mean scores of the pretest and posttest scores. The results of the analysis were as displayed in the table below.

Table 11: Paired samples t-test between pretest and posttest scores output

		Paired Differences					t	df	Sig. (2-tailed)
		M	SD	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest scores - Posttest scores	37	20.32	2.301	-41.621	-32.456	-16.1	77	0.000

The table shows that the test was significant. There was statistically significant difference in mean scores of the pretest and that of the posttest, t (77) = 16.1, p = .000 < .05.

6. Discussion

A Kruskal-Wallis H test showed that there was a statistically significant difference in mean rank test scores among the four study groups concerning their performance in MCT, χ^2 (3, N = 155) = 85.3, p = .000, with a mean rank test score of 130.8 for Experimental group1 (E1), 84.8 for Experimental group 2 (E2), 47.0 for Control group 1(C1) and 53.00 for Control group 2 (E2) and with the effect size of .60. The study showed that groups, which were taught by using hands-on genetics, had higher mean rank test scores than the control groups which were taught genetics through conventional-based methods of teaching. This implies that the experimental groups achieved significantly better test scores than the control groups. The results of this study, therefore, did not support the hypothesis which the study tested.

The result of this study can be interpreted in several ways. First, the use of hands-on materials tended to increase pupils' visualization of concepts in genetics lessons (Australian Academy of Science, AAS, 2009). Increased visual representation of concepts in genetics, as a result of using hands-on teaching, might have increased pupils' understanding of genetics in the experimental groups to a greater extent than was the case with the control groups. Additionally, Knippel (2008) suggests that genetics should be taught by teaching concepts which are at the organismic level (concrete) first before moving on to those at the cellular level (abstract level). Therefore, exclusion of concrete materials in the teaching of genetics might have negatively influenced pupils' performance in the control groups. Second, the use of hands-on teaching might have increased pupils' interest in learning genetics. A considerable number of studies in science education have shown that hands-on teaching affects pupils' motivation as well as their achievement (House, 2002; Tuan et al, 2003).

The magnitude of the effect size was found to be .60. An effect size of this magnitude is substantially large to have clinical (practical) relevance as far as pupils' achievement was concerned (Cohen, 1988). This implies that the difference in pupils' achievement arising from employing hands-on mode of teaching and conventional-based methods of teaching in teaching genetics was large enough to have a practical effect on pupils' learning of genetics. In this case, hands-on genetics was an effective intervention in teaching genetics as compared to the traditional mode of teaching (Cohen, 1988). As for the effect size between Control group1 (C1) and Control group 2 (C2), its actual value was very small, in fact the smallest of all the pairs. One possible explanation is that the two control groups were taught without the use of hands-on activities. It should however, be noted that despite yielding insignificant result and very small effect size, the two control groups had registered a gain in scores after instruction. This implies that both modes of teaching had contributed something towards pupils' learning of genetics, though to different extent: hands-on genetics yielded a much more gain score as compared to conventional-based mode of teaching. In view of this both modes of teaching seem to have a position in genetics education, but to varying degree.

The result of this study shows that if senior public secondary schools on the Copperbelt Province employ hands-on activities in their teaching of genetics, pupils are likely to achieve better test scores than they do when learn genetics using conventional-based modes of teaching.

7. Conclusion

The study showed a statistically significant difference in the mean scores of pupils who were taught genetics by using hands-on genetics from those who were taught the same concepts of genetics through conventional-based modes of instruction. That is, pupils who were taught by using hands-on genetics, on average, achieved higher test scores in genetics test than those who were taught concepts of genetics through traditional-based modes of instruction. Against this backdrop, the null hypothesis which claimed that there was no significant difference in the mean achievement test scores in genetics of pupils taught using hands-on genetics and those taught the same concepts of genetics through conventional-based methods was rejected.

8. Implications of the Study

Use of hands-on genetics resulted in improving pupils' performance in genetics test: much more than was the case when traditional-based modes of teaching were employed. It therefore, follows that this intervention has great potential to improve pupils' academic performance in genetics at secondary school level if appropriately applied to a classroom situation. Since hands-on genetics employed low cost materials, the said intervention is affordable and can be used in teaching genetics even by 'poor-resourced' schools. But resources still need to be made available for the implementation of the idea.

9. Recommendations

On the basis of the results of the study, the recommendations concerning hands-on genetics include the following:

1. Biology teachers should be encouraged to design low-cost hands-on materials by using locally available within their school environments.
2. Biology teachers should ensure that each practical activity is backed up by appropriate minds-on activities such as group discussion, exercises and challenging problem for them to solve so that pupils link practical work with the relevant concepts behind it.
3. As teachers employ hands- on materials on genetics, they should place emphasis on the development of pupils' conceptual understanding of genetics concepts as opposed to 'surface understanding of concepts' so as to reduce on the levels of rote learning.
4. School administrators should ensure that hands-on resources are made available for the implementation of hands-on genetics.

References

Abrahams, I., & Millar, R. (2008). Does Practical Work Really Work? A study of the effectiveness of Practical work as a teaching and learning method in school science. *International Journal of Science education, 30 (14) 1945-1969.*

Agogo, P.O., & Naakaa, D. A. (2014). Effects of 5es Constructivist Instructional Strategy on Students 'Interest in Secondary School Genetics in Gwer Local Government Area, Benue State, Nigeria, *Global Journal of Environmental Science and Technology.* ISSN-2360-7955, 1(2), 015-019.

Australian Academy of Science. (2009). *Literacy focuses across curriculum connections units,* primary connection project stage 3 from www.qualityteaching(2006-2008)deewi.gov.ali

Banet, E., & Ayuso, E. (2000). Teaching Genetics at Secondary School: A Strategy for Teaching about the Location of Inheritance Information. *Science Education*, 84, 313-351.

Chifwa, J. (2015). The teaching of genetics in selected secondary schools in Kitwe District, Zambia, *A master's dissertation, The University of Zambia.*

Chu, Y. (2008). Learning difficulties in Genetics and the development of related attitudes in Taiwanese Junior High School, *A doctoral thesis, University of Glasgow*.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Danmole, B.T., & Lameed, S.N. (2014). Exploring annotated drawing for improving Nigerian Secondary school students' achievement in genetics, International Journal of Biology Education 3(1).

Danmole, B.T., & Femi-Adeoye, K.O. (2004). Effect of concept mapping technique on senior secondary school students' Achievement and Retention of Ecology Concepts. Journal of the Science Teacher Association of Nigeria, 39 (1&2).

Dean-Paul, B &Kola, S, (2008). Correlations Among Jamaican 12th Graders' Five variables and Performance in Genetics. *Eurasian Journal of Mathematics, Science and Technology Education,* 4(1), 63-69.

Examination Council of Zambia Biology Paper II Chief examiner's report. (1992, 1997, 2005, 2006, 2009, and 2010). Lusaka: ECZ.

Fraenkel, J. R., & Wallen, N. E. (1993). *How to Design and Evaluate Research in Education, Second Edition*. New York: McGrawHil Inc.

Franzolin, F., & Bizzo, N. (n.d.) *Basic genetics content in secondary education: comparing high school teachers' and faculty members' opinions with the university curriculum*, University of Sao Paulo and Federal university of ABC, Brazil.

Haambokoma, C., & Kagamiyana, H, (2007). Nature and causes of Learning Difficulties in Genetics at High School Level in Zambia, *Journal of International Development and Co-operation*, 13(1), 1 – 7.

Haambokoma, C., Nkhata, B., Kostyuk, V.S., Chabalengula, V., Mbewe S., Tabakamulamu, M., Ndhlove, Z.B., Mushanga, R., & Nthani, R. (2002). *Strengthening of Mathematics and Science Education in Zambian Secodary schools: Baseline Study Report*, Lusaka, JICA-Zambia.

Hoppe, S.A. (2013). Teaching genetics using hands-on models, problem solving and inquiry-based teaching methods, *A master's thesis, Michigan State University.*

Huang, I.T., Huang, K., & Chung-wen (1993). Misconceptions of High School Students when *learning* genetics in the Republic of China, *Third Misconceptions seminar proceedings.*

Juap, S. (2004). The Conceptual Framework for Measuring Quality, Kathuri, N. J., & Pals, A. D. (1993). *Introduction to educational research*. Egerton University Education Book series.

Keogh, B. & Nayhor, S. (1996). Teaching and Learning in science. A new perspective on annotations presented at the BERA conference, Lancaster, www.gogglesearch.com

Knippel, M. (2002). *Copping with abstract and complex nature of genetics in biology education,* CD-β Press, Utrecht, The Neitherlands.

Kyoshaba, M. (2009). Factors affecting academic performance of undergraduate students at Uganda Christian University, *A master's dissertation, Makerere University.*

Marie-Christine, P.J.K, Arend, J.W. & Karst, T. B. (2005). Design Criteria for learning and teaching genetics, *Journal of biological Education,* 38(3).

Mugenda, O.M., & Mugenda. A.G. (1999). *Research methods: quantitative and qualitative approaches,* Nairobi, Kenya: ACTS Press.

Murray-Nseulu, M. (2011). Incorporating case studies into an undergraduate genetics course, *Journal of scholarship of Teaching and Learning,* 11(3), 75-85.

Nooriasfshar, M. (2004.) *The role of technology based approaches in globalizing education* in Teaching, Learning and Research Conference (4th), 22-25 Nov 2004, Ballarant, Victoria, Austrialia.

Osborne, J. (2015). *Practical work in science: Misunderstood and badly used?* SSR, 96 (357)

Topqcu, M.S., & Sahin-Pekmez, E. (2009.) Turkish middle school students' difficulties in learning genetics concepts, *Journal of Turkish Science Education,* 6(2).

Venville, G., & Donovan, J. (2008). How pupils use a model for abstract concepts in genetics. *Journal of Biological Education*, 43(1), 6-4. DOI: 10.1080/00219266.2008.9656143.

West African Examination Council Chief examiner's report. (2009, 2010, 2011 and 2012) Lagos: WAEC.

William, M.K. T. (2006). *Hybrid Experimental Design,* retrieved from https://www.socialresearchmethods.net/kb/exphybrd.php on 14th August, 2017.

Zywica, J., & Gomez, K. (2008). Annotating to Support Learning in the Content Areas: Teaching and Learning Science. *Journal of Adolescent and Adult Literature*, 52(2) retrieved 05/09/2012 from www.igenlit.pbworks.com/f/JAAL-52-2Zywica.pdf.