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Effects of Punnett Square and Beads Teaching Resources on Students' Retention in Mendelian Genetics in Secondary Schools in Uyo, Nigeria

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Abstract: *This study investigated the effectiveness of Punnett square and Beads teaching resources on students' retention in Mendelian genetics in Uyo Local Government Area. Four research questions and four null hypotheses were formulated to give direction to the study. Quassi-experimental research design was adopted for the study. The population of the study was 2,274 Senior Secondary Two (SS2) Biology students in all the fourteen coeducational secondary schools in Uyo. 192 SS2 Biology students from four co-educational secondary schools in the study area selected using purposive sampling technique formed the sample size. Mendelian Genetics Retention Test with a reliability index of 0.92 determined using kuder Richardson's formular- 21 was the instrument for data collection. The data collected were analyzed using mean, standard deviation, Analysis of Covariance and Regression. The result showed that the mean retention score of students taught Mendelian genetics using beads was significantly higher than those taught using Punnett square. Also, there was no significant influence of gender on the students' retention. With respect to interaction effects of treatment and gender on students' retention, the findings showed no statistically significant effects. However, the joint effects of treatment and gender on students' retention was statistically significant, accounting for 83.00 percent of the observed variation in students' retention. It was recommended among others, that Biology teachers should make use of Beads in teaching the concept.*

Key words: Punnett square, beads, instructional resources, mendelian genetics, retention, gender

INTRODUCTION

Mendelian genetics is a branch of Biology that deals with the study of genes, heredity and genetic variation in organisms. It accounts for similarities and variations between related individuals and also provides a foundation for biological studies. The laws of Mendelian inheritance help in understanding ecological adaptation and the principles of evolution. Good knowledge of Mendelian genetics also helps in understanding other areas of Biology like embryology and taxonomy. The study of Mendelian inheritance is interesting because it has a lot of practical

applications in our daily life (Maigoro, Nansoh, Pam and Micheal, 2017). Knowledge of genetics is used in producing improved varieties of plants and animals by breeders; it is used in detection and treatment of diseases, determination of paternity and detecting crime.

Genetics is a scientific concept that everyone needs to understand. Choden and Kijkunakul (2020) argued that genetics is the cornerstone of scientific literacy and demands students' comprehension and understanding. Williams, Montgomery and Manokore. (2015) also pointed out that genetics is a very important topic in today's society; therefore, students need to understand the basic principles of genetics to make informed choices in their lives. Educational systems around the world understand this need and genetic has become a well-established part of many national curriculum (Machora and Ehler,2021). Genetics is an integral part of our society because people come in contact with genetics in their daily lives yet the level of citizen's understanding is uncertain (Thorne, 2016).

Despite the various uses and application of genetics, research findings have shown that it is one of the most difficult aspects of Biology for both teachers and students (Alozie, Rogat and Krajcik, 2018*;* Agboghoroma and Oyorwi, 2015). Haga (2016) argued that although there is a high level of support for research in genetics, there is minimal conceptual understanding of it. This claim was supported by Thorne (2016) who argued that genetics is a subject that is both fascinating and difficult for students to understand. Alozie *et al*. (2018) argued that genetics content is not only complex but also abstract and difficult to relate to the daily lives and interest of students while Williams *et.al.* (2015) observed that students' difficulties in Mendelian genetics are related to the general problem that students have in understanding the basic concept of genes, alleles and chromosomes segregation that are fundamental to understanding how traits are transmitted from parents to offspring.

West Africa Examination Council Chief Examiners' Report (WAEC, 2015-2022) indicated that candidates had poor understanding of genetics and performed poorly in it. They proffered that teachers should lay emphasis on genetics and should attend seminars and workshops to improve on their teaching. Also, schools should provide teaching resources to help students understand biological concepts. Genetics is a very wide and difficult topic because it consists of unseen processes, the mechanisms are hard to understand because it is difficult to make the idea concrete without the use of appropriate tools but due to the use of inappropriate teaching method, the genetic idea of many students is very poor and full of confusion and misconceptions. Based on this, science educators have recommended the use of teaching resources to teach genetics (Evans, 2015; Tsui and Treagust, 2014).

Teaching resources are all the materials the teacher uses to assist the learners in their learning process. Rogers (2021) described teaching resources as tools which enable teachers to make learning meaningful to the students. The most important attribute of teaching resources is that, they enable ideas, events or objects that are complex or abstract to be presented in forms that are simple and visually concrete. As students interact with teaching resources, they are more likely to retain and relate their learning to new situations (Mayer, 2016). According to Hardman (2017), teaching resources encourage students to think deeply and creatively about scientific ideas, make their thinking visible and give teachers insight into their current understanding and

misconceptions. Punnett square and beads are teaching resources that can be used in the classroom to teach genetics in a meaningful way.

Punnett square is a graphical or visual way of discovery all of the possible combinations of genotypes that can occur in offspring given the genotype of their parents. According to Phelan (2018), Punnett square is a model that helps to show all possible allelic combinations of gametes in a cross of parents with known genotypes in order to calculate the probability of their children possessing certain sets of alleles. In particular, capital letters are used to represent dominant alleles and lower- case letters are used to represent recessive alleles. With this model, the known genotype of each parent is shown to help predict the possible genotypes of their offspring. It visualises how alleles are inherited or passed on to offspring from parents. It is typically used in monohybrid crosses and dihybrid crosses in which the theoretical outcomes are based on the assumption of segregation and independent assortment of genes according to Mendel's laws of heredity. William, Wasson, Barett, Greenall and Bailing (2021) used Punnett square to teach Hardy Weinberg equilibrium in population genetics in a private university and reported significant effect, the result also showed that Punnett square increases calculation proficiency for mathematics anxiety student. Also, Akpan and Etiubon (2023) investigated the effects of Punnett square and beads instructional resources on students' academic performance in genetics and observed that students taught with beads performed significantly better than those taught with Punnett square. Despite the usefulness of Punnett square in helping students to retain genetics concept, no work has been done on the effect of Punnett square on students' retention in genetics. This created a gap for the study.

Beads are teaching resources used in science classroom as analogical model to concretize the abstract nature of some scientific concepts. They help the teacher to clarify precise conceptions, and support him to make learning actual and active. As described by Venables and Tan (2017), analogical model is a teaching resource that helps people visualize objects and concepts which they are trying to understand and these models usually use a well-known object or concepts to instruct the learner about new and not well understood objects and concepts.

In genetic classroom, beads represent genes. Genes occur in pairs (alleles) and a pair of genes code for a particular character. The dominant genes are represented with a particular colour of bead while the recessive genes are represented with a different colour. Many Beads are involved but they must have 2 distinct colours, the idea is based on Mendel's law of segregation of genes. The beads are placed in two separate containers labelled father and mother, students pick one bead from the two containers one at a time, record the phenotype and genotype and also illustrate using genetic crosses. This engagement reduces the abstractness of genetics and makes learning meaningful which will also aid retention. Akpan and Etiubon (2023) and Dajal and Musa (2022) in separate studies reported significant effect of beads instructional resources on students' academic performance. In spite of the useful of beads in enhancing students' retention in genetics, there is no available literature to show the effect of beads on students' retention in secondary schools anywhere in the world, this created a gap for the study.

Retention is the ability to remember what has been learnt over a period of time. Bastanzhiyieva (2020) defined learning retention as a process by which acquired information is transferred from one's short-term memory to their long- term memory in such a way that it can easily and quickly

be retrieved when needed Several authors have pointed out that the way material is offered have a considerable effect on retention (Agu and Samuel, 2018; King, 2021). According to Watkins (2019), learners benefit most from instruction when they are more engaged and are not bored. This is achieved when the learning environment is interactive. This is also supported by King (2021) who argued that getting learners involved encourage knowledge recall and adds fun to the learning and if something is fun, there is a better chance of remembering it. Andriotis (2017) pointed out that when a concept is abstract, it is difficult to retain it and argued that one of the easiest retention techniques is to apply learning to the real-world experience of the students. Also, all the students should be fully engaged in the learning process irrespective of their gender.

Gender refers to being male or female in accordance with the cultural and social responsibilities that are considered suitable for men and women. Research on genetics education shows inconsistent findings on the influence of gender on students' retention in genetics. Some studies show no significant influence of gender on students' retention in genetics. (Akpan and Etiubon, 2023; Khalid, Danladi and Adamu, 2023). Others indicate that female students have better achievement in genetics than male students. (Nnodim and Ndioho, 2023). While others reported that males performed significantly better than females (Dajal and Musa, 2022). Based on these inconsistencies, gender was an intervening variable in this work.

Research Questions

The following research questions were answered:

1. What is the difference between the mean retention scores of students taught Mendelian genetics using Punnett square and those taught using Beads?
2. What difference exists between the mean retention scores of male and female students taught Mendelian genetics using Punnett square and those taught using Beads?
3. What is the interaction effect of treatment and gender on students' retention in Mendelian genetics?
4. What is the joint effect of treatment and gender on students' retention in Mendelian genetics?

Research Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

Ho1 There is no significant difference between the mean retention scores of students taught Mendelian genetics using Punnett square and those taught using Beads.

Ho2 There is no significant difference between the mean retention scores of male and female students taught Mendelian genetics using Punnett square and those taught using Beads.

Ho3 There is no significant interaction effect of treatment and gender on students' retention in Mendelian genetics.

Ho4 There is no significant joint effect of treatment and gender on students' retention in Mendelian genetics.

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METHODOLOGY

The study was quasi-experimental research using a non-randomized pre-test and post-test design. The area of the study was Uyo local Government Area of Akwa Ibom State. The population of the study comprised all senior secondary two Biology students (SS2) in all the fourteen coeducational secondary school in Uyo Local government area. The population was 2,274 for 2022/2023 session. Sample of 192 SS2 students in four co-educational secondary schools in the study area were selected for the study using purposive sampling technique. The research instrument was a researcher made test titled "Mendelian Genetics Retention Test" (MGRT). It comprised 50 multiple choice objective test items. Face validity of the instrument was done by three experts. The content validity of the MGRT was ensured using the test blue print. The reliability of the instrument was 0.92 determined using Kuder-Richardson 21 formula (KR-21). Each correct answer chosen was scored one mark and an incorrect answer was scored zero mark.

Two groups were used for the study: Experimental Group 1, and Experimental Group 2. A pre-test on Mendelian genetics using the researchers Mendelian Genetics Performance Test (MGPT) was administered to the two groups in all the sampled schools to determine the students' base line knowledge on the concept of genetics. Thereafter, the students in experimental group 1 were taught Mendelian genetics using Punnett square while the students in experimental group 2 were taught using Beads. The researcher and the research assistants in the sampled schools were involved in the teaching using the lesson notes written by the researcher. The MGPT was administered to the students immediately after the treatment as post-test while MGRT, a reshuffled form of post-test was administered three weeks after administering the post test. Test scripts from the pre-test, post-test and retention test were collected, scored and subjected to statistical analysis.

RESULTS

Research Question one: What difference exists between the mean retention scores of students taught Mendelian inheritance using Punnett square and those taught using Beads?

Table 1 Mean (□) and standard deviation of students' mean retention scores classified by treatment groups

Treatment Groups	N	Post-test		Retention		Mean Gain Score
		□	SD	□	SD	
Punnett Square	96	35.75	2.51	30.87	2.34	- 4.88
Beads	96	42.10	1.94	40.60	2.22	- 1.50

Table 1, shows the post-test and retention mean scores and standard deviation of scores of students taught Mendelian genetics using Punnett square and those taught using Beads. The post-test and retention mean scores are 35.75and 30.87respectively, for those in Punnett Square group and the retention - post-test mean difference score is - 4.88 The post-test and retention mean scores of those taught using Beads are 42.10 and 40.60, respectively; with retention - post-test mean score difference of -1.50 The observed retention -post-test mean scores difference show students taught using Beads retained the concepts better than those taught using Punnett Square.

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Hypothesis one: There is no significant difference between the mean retention scores of students taught Mendelian genetics using Punnett square and those taught using Beads.

Table 2: Summary of Analysis of Covariance (ANCOVA) of the students' retention scores classified by treatment groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	5207.23[a]	2	2603.62	1759.02	.00	S
Post test (Covariate)	663.71	1	663.71	448.41	.00	S
Treatment	312.42	1	312.42	211.08	.00	S
Error	279.75	189	1.48	-	-	-
Total	250732.00	192	-	-	-	-
Corrected Total	5486.98	191	-	-	-	-

R Squared = .949 (Adjusted R Squared = .948)

In Table 2, the calculated F-ratio for the effect of instructional resources on the students' retention at df 1, 189 is 211.08 while its corresponding calculated level of significance is 0.00 alpha. This level of significance is less than 0.05 in which the decision is based; indicating that there was a significant difference between post-test and retention mean scores of students taught Genetics using Punnett Square and those taught using Beads. With this observation, null hypothesis 1 was rejected. The mean scores difference in Table 2, showed direction of significance was in favour of those taught using Beads

Research Question two: What difference exists between the mean retention scores of male and female students taught Mendelian inheritance using Punnett square and those taught using Beads?

Table 3: Mean and standard deviation of students' post-test and retention scores classified by treatment groups and gender

Treatment Groups	Gender	N	Post-test		Retention		Mean Score Difference
			□	SD	□	SD	
Punnett Square	Male	43	35.84	2.36	31.21	2.09	-4.63
	Female	53	35.68	2.65	30.60	2.33	-5.08
Beads	Male	41	42.28	1.99	40.89	2.32	-1.39
	Female	55	42.06	1.94	40.54	2.21	-1.52

Table 3, shows the post-test and retention mean scores and standard deviation scores of male and female students taught Mendelian inheritance using Punnett Square and those taught using Beads. The mean scores difference displayed show that, in all, the males taught using Beads had the best retention; followed by their female counterparts in the same group.

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Hypothesis two: There is no significant difference between the mean retention scores of male and female students taught Mendelian inheritance using Punnett Square and those taught using Beads.

Table 4 Summary of Analysis of Covariance (ANCOVA) of male and female students' retention scores classified by treatment groups and gender with post test scores as covariate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	5213.00[a]	4	1303.25	889.53	.00	S
Posttest (Covariate)	658.98	1	658.98	449.79	.00	S
Treatment	284.34	1	284.34	194.07	.00	S
Gender	3.79	1	3.79	2.59	.11	Ns
Treatment * Gender	.82	1	.82	.56	.45	Ns
Error	273.98	187	1.47	-	-	-
Total	250732.00	192	-	-	-	-
Corrected Total	5486.98	191	-	-	-	-

a. R Squared = .950 (Adjusted R Squared = .949)

In Table 4, the calculated F-ratio for the main effect of teaching resources on the students' retention at df 1, 187 is 194.07, while its corresponding calculated level of significance is 0.00 alpha. This level of significance is less than 0.05 in which the decision is based; indicating that there was a significant difference between the retention scores of students on the concepts taught given the instructional resources used. However, the F-cal value for the main effect of gender at df 1, 187 was 2.59 while its significant level is 0.11. This significant level is greater than 0.05 alpha in which the decision is based, indicating that the influence of gender on the students' retention was not statistically significant. With this observation, null hypothesis 2 was upheld.

Research Question three: What is the interaction effect of treatment and gender on students' retention in Mendelian genetics?
This research question was answered alongside hypothesis three using the results in Table 5

Hypothesis three: There is no significant interaction effect of treatment and gender on students' retention in Mendelian genetics

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Table 5: Summary of Analysis of Covariance (ANCOVA) of male and female students' retention scores classified by treatment groups and gender with post test scores as covariate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	5213.00[a]	4	1303.25	889.53	.00	S
Posttest (Covariate)	658.98	1	658.98	449.79	.00	S
Treatment	284.34	1	284.34	194.07	.00	S
Gender	3.79	1	3.79	2.59	.11	Ns
Treatment * Gender	.82	1	.82	.56	.45	Ns
Error	273.98	187	1.47	-	-	-
Total	250732.00	192	-	-	-	-
Corrected Total	5486.98	191	-	-	-	-

a. R Squared = .950 (Adjusted R Squared = .949)

In Table 5, the calculated F-ratio for the interaction effects of treatment and gender on the students' retention at df 1, 187 is 0.56, while its corresponding calculated level of significance is 0.45 alpha. This level of significance is greater than 0.05 in which the decision is based; indicating that there was no significant interaction effects of treatment and gender on the retention of the students on the concepts taught. With this observation, null hypothesis 3 was upheld. With respect to research question 3, the observation indicates that the two instructional resources had the same effects on the two levels of gender, and vice versa.

Research Question four: What is the joint effect of treatment and gender on students' retention in Mendelian genetics?

Table 6 Summary of Regression Analysis of students' retention scores classified by treatment groups and gender.

Model	R	R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change
1	.911[a]	.830	2.22	.830	460.93	2	189	.000

In Table 6, the square of the adjusted multiple regression index, R Squared, for the joint effect of treatment and gender on students' retention, is 0.830. This observation shows that treatment and gender jointly explained 83.00% of the observed variations in students' retention. This answered research question four.

Hypothesis four: There is no significant joint effect of treatment and gender on students' retention in Mendelian genetics
Table 6 refers.

In Table 6, the calculated F change, for the joint effect of treatment and gender on students' performance in Mendelian genetics is 460.93 at df 2, 189, while its calculated significant level is 0.00. This level of significance is less than 0.05 in which the decision is based; indicating that there

was a significant joint effect of treatment and gender on the retention of the students on the concepts taught. With this observation, null hypothesis 4 was rejected.

DISCUSSION OF FINDINGS

On the effects of Punnett Square and Beads on students' retention, the findings showed there was a significant difference between the retention scores of students taught Genetics using Punnett Square and those taught using Beads in favour of students in Beads group. This observation could be because the Beads activities captivated students' attention and motivated their interest. The beads activities also elicited the curiosity of the students and this facilitated understanding and assimilation, Also, the learning was related to the real world, the students are already familiar with beads, this help to connect the new learning with the existing knowledge of the students and enhanced retention of the concept. This finding agrees with the findings of Akpan and Etiubon (2023) who reported significant difference in the academic performance f students taught genetics using Punnett square and those taught using beads in favour of those taught using beads.

With respect to the effect of gender on the students' retention given the teaching resources, the findings showed that there was no significant difference between the retention scores of male and female students in the concepts taught given the teaching resources used. The observation indicates that the two teaching resources were gender friendly, and all the students in the two groups benefitted from the instructions given. This agrees with the findings of Akpan and Etiubon (2023) who reported no significant influence of gender on the academic performance of students taught genetics using Punnett square and beads but contradicts the findings of Dajal and Musa (2022) who reported significant influence of gender on the academic performance of students taught genetics using beads and expository method in favour of male students.

On the interaction effects of treatment and gender on students' retention, the findings showed there was no significant interaction effects of treatment and gender on the retention of the students on the concepts taught. The two teaching resources had the same effects on the two levels of gender, and vice versa.

With respect to the joint effects of treatment and gender on students' retention the findings showed there was a significant joint effect of treatment and gender on the retention of the students on the concepts taught. Treatment and gender jointly contributed 83.00 percent to the observed variations in students' retention.

CONCLUSION

Based on the findings of the study, it was concluded that the Beads are more effective than the Punnett Square in enhancing students' retention in Mendelian genetics. Also, that gender has no significant influence on students' retention in Mendelian genetics.

Recommendations

Based on the findings, the following recommendations were made:

1. Biology teachers should make use of Punnett Square and Beads in enhancing meaningful learning of genetics
2. Curriculum planners should incorporate Punnett Square and Beads as resources for teaching genetics in the curriculum.
3. Science Teachers Association of Nigeria should organise workshop for Biology teachers on the use of beads and Punnett square in teaching genetics

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