Effects of Punnett square and beads instructional resources on the academic performance of secondary school students in Uyo, Nigeria.

Mary Effiong Akpan and Dr Rebecca U. Etiubon

Department of Integrated Science
College of Education, Afaha Nsit
akpan.mary2@gmail.com

&

Department of Science Education,
University of Uyo, Uyo.

Abstract

This study investigated the effects of Punnett square and Beads instructional resources on the academic performance of Secondary Schools students in Genetics in Uyo, Nigeria. The study was a quassi-experimental research with non- randomized pre-test post-test design. One research question and four null hypotheses gave direction to the study. The study population comprised all the 2,296 Senior Secondary Two (SS2) Biology students in all the fourteen (14) coeducational secondary schools in Uyo Local Government Area for 2022/2023 school session. The study sampled comprised 192 SS2 Biology students in four intact classes in four co-educational secondary schools in the study area selected using Criterion sampling technique. The instrument for data collection was a researcher –developed 50-item multiple choice test tagged: Genetics Performance Test (GPT) with a reliability index of 0.93, determined using Kuder Richardson's formula - 21. The data collected from all the tests were analyzed using Analysis of Covariance (ANCOVA) and Regression. The result showed that there was a significant difference in the academic performance of students in Genetics when taught using Punnett square and beads, in favour of those taught using Beads. Also, gender had no significant influence on the students' performance. With respect to interaction effects of treatment and gender on students' performance, the findings showed no statistically significant effect. However, the joint effect of treatment and gender on students' performance was statistically significant, accounting for 67.00 percent of the observed variation in students' performance. Consequently, it was recommended that Biology teachers should make use of Beads in teaching Genetics.

Keywords: *Punnett square, beads, instructional resources and gender*

Introduction

Biology is a science subject concern with the study of living things and their vital processes. It deals with the origin, morphology, anatomy, physiology, behaviour and the distribution of living things. Biology is both captivating and fun to study at the secondary level especially when connected to real life experience. According to Marteins (2018), the goal of Biology is to test theories formulated about living things by using the scientific method and then apply the findings in a beneficial way. One of the benefits of studying Biology as a subject is that it provides a link between school Biology and everyday life. Despite the fact that Biology is an interesting subject, research has shown that the performance of students in Biology in Nigeria is poor and has not improved over the years as indicated by West Africa Examination Council Chief Examiners' Reports (WAEC, 2015-2021). This persistent poor performance of students in Biology shows that a good number of students who enrol for Biology in public examination graduate without understanding the fundamentals of the subject. Akpeli (2019) outlined the problems militating against the performance of the objectives of Biology education as follows: emphasis is on passing examination to meet the requirement for admission in tertiary institution; shortage of experience and dedicated manpower; poor state of teacher training institution; inappropriate or ineffective teaching strategies, lack of equipped laboratories and funding.

Genetics is a concept in Biology that is concern with the study of the mode of transmission of hereditary characteristics from parents to offspring. It accounts for similarities and variations between related individuals. The study of Genetics can be intellectually fascinating because it has a lot of practical applications in our daily life (Maigoro, Nansoh, Pam & Micheal, 2017). Breeders require the knowledge of genetics to produce desired varieties of plants and animals; the idea of genetics is also required in the detection and treatment of diseases, exonerating innocent people who are accused of crime and identifying the culprits as well as determination of paternity. Choden & Kijkunakul (2020) noted that Genetics is the cornerstone of scientific literacy and demands students' comprehension and understanding. Williams, Montgomery & Manokore (2015) also pointed out that Genetics is a very important topic in modern 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 genetics have become a well-established part of many national curriculum (Machora & Ehler, 2021).

Despite the various uses and application of genetics, research findings have shown that it is among the most difficult aspect of Biology for both teachers and students (Alozie,

Eklund, Rogat & Krajcik.,2018; Agboghoroma & Oyorwi, 2015). This fact was buttressed by Thorne (2016) who noted that Genetics is a subject that is interesting but requires more effort for students to understand. Williams et al. (2015) explained that Genetics generally involves invisible processes at different organizational levels and as such, Genetics has been described as abstract. Students' difficulties in Genetics are related to its abstractness, complexity, terminologies that are confusing and calculations involved in the concept.

West Africa Examination Council Chief Examiners' Reports (WAEC, 2015 to 2021) indicated that candidates had poor understanding of Genetics and performed poorly in it. This persistent poor performance of students in Genetics in standardized examination shows that the topic has not been properly taught to the students. Genetics is a broad and complicated concept, the processes are difficult to understand because it is hard to make the idea visible without the use of teaching aids but due to the use of inappropriate teaching method, genetic idea of students is poor and confusing. On this note, researchers supporting constructivism have recommended the use of instructional resources to teach Genetics (Evans, 2015; Tsui & Treagust, 2014).

Instructional resources are all the materials the teacher uses to assist the learners in their learning process, they are all the materials which appeal to all the senses and enrich learning. Rogers (2021) described instructional resources as tools which enable teachers to make learning meaningful to the students. The most important attribute of instructional 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 instructional resources, they are more likely to retain and relate their learning to new situations (Mayer, 2016). According to Hardman (2017), instructional resources encourage students to think deeply and creatively about scientific ideas and give teachers idea about their understanding and misconceptions. Instructional resources help students understand complex scientific ideas that are not visible. Punnett square and bead activity models are instructional resources that can be used in the classroom to aid students understand the abstract nature of Genetics in order to make learning meaningful.

Punnett square is a visual way of discovering all the possible genotypes that can occur in offspring given the genotype of their parents. According to Phelan (2018), Punnett square is a model that shows all possible combination of alleles in a cross of parents with known genotypes, this helps in calculating the possibility of the children inheriting certain traits from the parents. In particular, capital letters are used to indicate dominant alleles and

small letters are used to represent recessive alleles. Using this model, the known genotype of each parent is used to predict the feasible genotypes of their children. It is normally used in crosses that involve one or two traits in which the theoretical outcomes depend on Mendel's law of segregation and independent assortment of genes. Senthil (2019) summarized the importance of using Punnett square in the classroom to teach Genetics to include: preventing misconceptions, understanding genetic terminologies, making abstract ideas concrete, understanding possible genotypes that result from fertilization, understanding the segregation pattern of alleles and chromosomes during sexual reproduction and solving genetic mathematical problems. Despite the benefits of punnet square, there is no available data to validate its used in secondary schools both in Nigeria and foreign context. However, 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 indicated that Punnett square increases calculation proficiency for mathematics anxiety students.

On the other hand, Beads are instructional resource used in science classroom as conceptual models to concretize the abstract nature of some scientific concepts. Conceptual models rely on using familiar objects to describe ideas that are abstract. In genetic classroom, beads represent genes or different forms of genes also known as alleles. Many beads are used to demonstrate how characters are transmitted from parents to children. The beads have two distinct colours, a particular colour indicate a dominant gene and another colour, a recessive gene. The beads are kept in two different containers labelled mother and father. Students picked one bead from the two containers one at a time and record the genotype and phenotype and also illustrate genetic crosses. The idea is based on segregation pattern of chromosome during sexual reproduction. Male and female students are involved in the activity and benefit equally from it. Dajal and Musa (2022) reported significant effect of beads instructional resource on students' performance in Genetics.

Gender refers to the social features and opportunities of being male and female. Information on gender and students' academic performance in Biology is inconclusive. For instance, Dajal & Musa (2022); Akhighe & Ogufere (2020); Adelana & Ajayi (2020) in separate studies reported no significant influence of gender on students' performance in Genetics. Akpan & Edem (2023) reported a significant influence of gender on students' academic performance in Genetics in favour of the male students while Onyejekwe, Uchendu & Tochi (2018) reported that female student score significantly higher than male students in Genetics. Based on the contradictory information, gender was a moderating variable in the study.

Research Question

1. What is the joint effect of treatment and gender on students' performance in Genetics?

Research Hypotheses

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

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

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

Ho3 There is no significant interaction effect of treatment and gender on students' performance in Genetics.

Ho4 There is no significant joint effect of treatment and gender on students' performance in Genetics.

Methodology

The research design was quassi-experimental pre-test, post-test non-equivalent group. The research was carried out in Uyo Metropolis. The population of the study consisted of all senior secondary two Biology students (SS2) in all the fourteen coeducational secondary school in Uyo Local government area. The population was 2,296 for 2022/2023 session. Sample size of 192 SS2 students in four co-educational secondary schools in the study area were selected for the study using Criterion sampling technique. The research instrument was a researcher made test titled "Genetics Performance Test", it comprised 50 multiple choice objective test items. Face validity of the instrument was done by three experts while the content validity was ensured using the test blue print. The reliability of the instrument was 0.93, determined using Kuder-Richardson 21 formula (KR-21). Each correct answer was scored one mark and an incorrect answer was scored zero. The data collected were analysed using Mean, Standard deviation, Analysis of Covariance (ANCOVA) and Regression. All the hypotheses were tested at 0.05 level of significance.

Results

Hypothesis One: There is no significant difference in the mean performance scores of students taught Genetics using Punnett square and those taught using Beads.

Table 1: Summary of Analysis of Covariance (ANCOVA) of the students' performance scores classified by treatment groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	2229.05 [a]	2	1114.53	316.32	.000	S
Pretest (Covariate)	291.03	1	291.03	82.60	.000	S
Treatment	2086.77	1	2086.7	592.25	.000	S
Error	665.93	189	3..52	-	-	-
Total	293836.00	192	-	-	-	-
Corrected Total	2894.979	191	-	-	-	-

R Squared = .770 (Adjusted R Squared = .768)

In table 1, the calculated F-ratio for the effect of instructional resources at df 1, 189 is 592.25 while its corresponding calculated level of significance is .000 alpha. This level of significance is less than 0.05 in which the decision is based; indicating that there is a significant difference between the performance of students taught Genetics using Punnett Square and those taught using Beads. With this observation, null hypothesis 1 was rejected. The mean gain scores showed direction of significance was in favour of those taught using Beads.

Table 2: Summary of Analysis of Covariance (ANCOVA) of male and female students' performance scores classified by treatment groups and gender with pre-test scores as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	2230.01 [a]	4	557.50	156.78	.00	S
Pretest (Covariate)	290.73	1	290.72	81.76	.00	S
Treatment	1561.29	1	1561.29	439.06	.00	S
Gender	.00	1	.00	.00	.99	Ns
Treatment * Gender	.91	1	.91	.26	.61	Ns
Error	664.97	187	3.56	-	-	-
Total	293836.00	192	-	-	-	-
Corrected Total	2894.98	191	-	-	-	-

a. R Squared = .770 (Adjusted R Squared = .765)

In Table 2, the F-cal value for the main effect of gender at df 1, 187 was 0.00 while its significant level is 0.99. This significant level is greater than .05 alpha in which the decision is based, indicating that the influence of gender on the students' performances was not statistically significant. With this observation, null hypothesis 2 was upheld.

Hypothesis three: There is no significant interaction effect of treatment and gender on students' performance in Genetics.

Table 3: Summary of Analysis of Covariance (ANCOVA) of male and female students' performance scores classified by treatment groups and gender with pre-test scores as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	2230.01[a]	4	557.50	156.78	.00	S
Pretest (Covariate)	290.73	1	290.72	81.76	.00	S
Treatment	1561.29	1	1561.29	439.06	.00	S
Gender	.00	1	.00	.00	.99	Ns
Treatment * Gender	.91	1	.91	.26	.61	Ns
Error	664.97	187	3.56	-	-	-
Total	293836.00	192	-	-	-	-
Corrected Total	2894.98	191	-	-	-	-

a. R Squared = .770 (Adjusted R Squared = .765)

In Table 3, the calculated F-ratio for the interaction effects of treatment and gender on the students' performance at df 1, 187 is 0.26, while its corresponding calculated level of significance is 0.61 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 performance of the students on the concepts taught. With this observation, null hypothesis 3 was upheld.

Research Question one: What is the joint effect of treatment and gender on students' performance in Genetics?

Table 4: Summary of Regression Analysis of students' post test 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	.818[a]	.670	2.25	.670	191.75	2	189	.000

In Table 4, the square of the adjusted multiple regression index, R Squared, is 0.670. This observation shows that treatment and gender jointly contributed 67.0% to the observed variations in students' performance. This answered research question 1

Hypothesis four: There is no significant joint effect of treatment and gender on students' performance in Genetics.

Table 4 refers.

In Table 4, the calculated F change, for the joint effect of treatment and gender on students' performance in Genetics is 191.75 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 performance of the students on the concepts taught. With this observation, null hypothesis 4 was rejected.

Discussion of Findings

The findings with regard to the effects of Punnett Square and Beads on students' performance in Genetics showed that there was a significant difference between the mean performance scores of students taught Genetics using Punnett Square and those taught using Beads, in favour of those taught using Beads. The better performance of the students in Beads group compared with Punnett Squares could be attributed to Beads activities to actively engage the learners in the teaching-learning process; captivated and sustained the learners' interest throughout the learning process, this facilitated proper assimilation and comprehension of the concept. This finding agrees with the findings of Dajal & Musa (2022) who reported that the use of beads instructional resource in teaching Genetics yielded significantly better results than expository strategy. Unfortunately, no available and accessible empirical reports compared the effectiveness of Punnett Squares and Beads in facilitating students' performance.

Findings on influence of gender on students' performance when taught using Punnett Squares and Beads, indicated that there was no statistically significant difference between the academic performance of male and female students in the concepts taught given the instructional resources used. This observation indicates that gender is not a strong determinant of students' academic performances given the instructional resources used. The no significant influence of gender on treatment agrees with the findings of Dajal & Musa (2022) who reported no significant influence of gender on students' performance taught Genetics using Beads but contradicted the findings of Akpan & Edem (2023) who reported that male students scored significantly better than females in Genetics.

The findings with respect to interaction effects of treatment and gender on students' performance showed there was no significant interaction effects of treatment and gender on the performance of the students on the concepts taught. That is, the two instructional

resources had the same effects on the two levels of gender, and vice versa.

The findings with respect to joint effects of treatment and gender on students' performance in Genetics showed there was a significant joint effect of treatment and gender on the performance of the students on the concepts taught. Treatment and gender jointly contributed 67.00percent to the observed variations in students' performance.

Conclusion

Based on the findings of the study, it was concluded that the Beads are more effective than the Punnett Square in facilitating students' performance in Genetics. Also, gender is not a significant factor on students' performance in Genetics.

Recommendations

Based on the finding, the recommendations made were:

1. Biology teachers should use Punnett Square and Beads in facilitating students understanding 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 organize a regular workshop to train Biology teachers on the use of Punnett Square and Beads in teaching Genetics.

References

Adelana, O. P. and Ajayi, O. (2020). Effectiveness of multimedia self-learning package in teaching and learning of Genetics in secondary schools. *Journal of Psychometry and Assesment Technique,* 19(1), 11-43.

Agboghoroma,T. E. and Oyorwi, E. O. (2015). Evaluating effect of students 'academic achievement on identified difficult concepts in senior secondary school in Biology in Delta State. *Journal of Education and Practice,* 6(30), 117-125.

Akhigbe, J. and Ogufere J. (2019). Effects of computer simulation instructional strategy on students' attitude and academic achievement in Genetics. *Journal of Social Science* 5 (4),
32-4

Akpan, M. E. and Edem, U. P. (2023). Influence of blended instructional strategy on Students academic performance in Genetics. *National Journal of Science and Technology* 9(1), 53-60.

Akpeli, A. O. (2019). The role of Biology Education in Nigeria national-development. https://www.dutable.com/2019/02/16/the-roleofBiology-education-in (Retrieved on 3rd May, 2021).

Alozie, N., Eklund, J., Rogat, A. and Krajcik, J. (2018). Genetics in the 21st century: The Benefits and challenges of incorporating a project-based Genetics unit in Biology classrooms. *The American Biology Teacher,* 72(4), 225-230.

Choden, T. and Kijkunakul, S. (2020). Blended problem- based learning with scientific Argumentation to enhance students' understanding of basic Genetics. *International Journal of Instruction,* 13(1), 445-462.

Dajal, R. G. and Musa, P. E. (2022). Effects of beads instructional resource on senior secondary students' attitude and performance in Genetics in Nasarawa state, Nigeria. *International Journal of Innovative Social and Science Education Research,* 10(3), 11-16.

Evans, S. W. (2015). The dooly mixture model of the DNA double helix. *School Science Review,* 84(6), 15-16.

Hardman, M. A. (2017). Models, matter and truth in doing and learning science. *School Science Review,* 98(365), 91-98.

Machora and Ehler (2021). Secondary school students' misconceptions in Genetics: Origin and solutions. *Journal of Biological Education*, 25(15), 61-68.

Maigoro, I. L., Nansoh, M. D., Pam, E. D. and Michael, W. (2017). The relationship between types of misconceptions and performance in Genetics among senior secondary school Biology students in Jos North LGA of Plateau State. *International Journal of Quantitative and Qualitative Research Method,* 5(3), 12-20.

Marteins, H. (2018). Aims and objectives of studying Biology .https://www.theclassroom.com/ aims-objectives-studying biology-844905-html. (Retrieved 3rd May, 2021)

Mayer, R. E. (2016). The promise of multimedia learning: Using the same instructional design methods across different media. *Learning and Instruction,* 13(10), 152-160.

Onyejekwe, C. A., Uchendu, C. G. and Nmom, T. (2018). Effects of concept mapping on students' performance in Genetics in secondary schools in Obio Akpor. *International Journal of Education and Evaluation,* 4(1), 1-7.

Rogers, K. (2021).Scientific modelling. (Retrieved 30th November, 2021).

Sakopta, A. (2021). Punnet square –definition, types, application, examples, limitations. https//www.microbenotes.com/Punnett-square (Retrieved on 23rd September, 2021)

Senthil, D. (2019). Why are Punnett squares useful in Genetics? squares. (Retrieved 20th December, 2021).

Thorne, K. (2016). Teaching Genetics- a linguistic challenge. A classroom study of secondary teachers' talk about genes, traits and proteins. . (Retrieved on 12th September, 2021).

Tsui, C.Y. and Treagust, D. (2014). Motivational aspects of learning Genetics with interactive multimedia. *The American Teacher,* 66 (7), 277-285.

West African Examination Council (2015- 2021). *Chief Examiners Report in Biology*: Lagos.

Williams, M., Montgomery, B. L. and Manokore, V. (2015). From phenotype to genotype: Explaining middle school students' understanding of Genetics. *The American Biology Teacher,* 10(6), 50-61

William, K. R., Wasson, S. R., Barett, A., Greenall, R. F., Jones, S.R. and Bailig, E. G. (2021). Teaching Hardy Weinberg equilibrium using population level Punnett square: Facilitating calculation for students with Math anxiety. *Life Sciences Education,* 20(2), 50-55.