



## EFFECTS OF MANIPULATIVE INSTRUCTIONAL MATERIALS ON SECONDARY SCHOOL STUDENTS' LOWER-ORDER THINKING IN GENETICS IN SOKOTO STATE, NIGERIA

BY

**Bello, Shamsudeen**

Department of Science Education,  
Sokoto State University, Sokoto.  
Shamsudeen.bello@ssu.edu.ng + 08032890327

&

**Hussaini, Naziru**

Department of Science Education,  
Sokoto State University, Sokoto.  
naziruhussaini@gmail.com | 08165095038

---

### Abstract

The study examined the effect of manipulative instructional materials (MIMs) on secondary school students' lower-order thinking in genetics in Sokoto State, Nigeria. A quasi-experimental design involving 378 Senior Secondary School Three (SS3) biology students from four public schools was adopted. Participants were assigned to experimental and control groups. The experimental group was taught genetics using manipulative instructional materials, while the control group received instruction through conventional methods. Data were collected using the Genetics Lower-Order Thinking Test (GLOTT), a validated and reliable instrument designed to assess students' ability to recall, comprehend, and apply genetic concepts. Descriptive statistics (mean and standard deviation) and inferential statistics (independent samples t-test) were used for data analysis. Findings revealed that students exposed to manipulative instructional materials performed significantly better in lower-order thinking tasks than those taught using non-manipulative instructional materials. Results further indicated no significant gender difference among students taught with MIMs. It was concluded that manipulative instructional materials provide an effective strategy for enhancing foundational learning in genetics. The study recommends that biology teachers incorporate MIMs into instructional practice and that education authorities ensure their consistent use in teaching genetics concepts.

**Keywords:** Manipulative Instructional Materials, Lower-Order Thinking, Biology Education, Genetics

---

### INTRODUCTION

Effective science education relies heavily on the availability and appropriate utilization of instructional materials that make learning meaningful and comprehensible. Instructional materials refer to all teaching aids visual, auditory, tactile, and digital—used by teachers to facilitate understanding and retention of concepts (UNESCO, 2021; Oyelekan & Bello, 2019). These materials help bridge the gap between theoretical explanations and practical experiences, thereby

enhancing learners' cognitive engagement and retention.

Instructional materials are broadly categorized into manipulative and non-manipulative types. Manipulative instructional materials (MIMs) are physical or virtual resources that students can handle, construct, or experiment with to gain hands-on experience. Examples relevant to genetics instruction include DNA and chromosome models, gene

mapping kits, and Punnett square manipulatives. These tools promote active participation by allowing learners to physically explore concepts and visualize processes that are otherwise abstract (Bello & Aminu, 2019). In contrast, non-manipulative instructional materials (NMIMs) such as chalkboards, charts, printed diagrams, and textbooks convey information passively and primarily support teacher-centered instruction. Although NMIMs assist in content delivery, they often limit learners to rote memorization rather than conceptual understanding (Arop, 2015).

In the context of Bloom's Revised Taxonomy, manipulative instructional materials (MIMs) play a crucial role in supporting the lower levels of cognitive development remembering, understanding, and applying (Anderson & Krathwohl, 2001; Krathwohl, 2022).

At the *remembering* level, students recall genetic terms, such as gene, allele, or phenotype, by associating them with tangible models. At the *understanding* level, they explain concepts like Mendelian inheritance using Punnett squares or physical models. At the *application* level, they use these materials to predict genetic outcomes and apply learned principles to simple genetic crosses. Through these processes, MIMs help solidify foundational knowledge that is essential for advancing to higher cognitive levels in subsequent learning stages.

Genetics, a core unit of the secondary school biology curriculum, focuses on the study of heredity and variation. It introduces learners to basic concepts such as genes, chromosomes, alleles, genotypes, and phenotypes, as well as to simple Mendelian principles. Mastery of these fundamental concepts requires strong lower-order thinking skills (LOTS), which enable students to recall facts, comprehend processes, and apply learned rules to basic inheritance patterns. Unfortunately, reports from the West African Examinations Council (WAEC, 2015–2021) and the National Examinations Council (NECO, 2010–2015) reveal persistent weaknesses among Nigerian students in recalling definitions, explaining genetic terms, and

solving monohybrid crosses—tasks that reflect deficiencies in lower-order thinking.

The use of manipulative instructional materials offers a promising approach to addressing these challenges. MIMs allow students to see, touch, and manipulate representations of genetic components, thereby making abstract concepts concrete. Such interaction enhances memory retention, comprehension, and conceptual application (Moyer-Packenham & Westenskow, 2019).

Furthermore, MIMs support differentiated learning by engaging students of diverse abilities and interests, fostering both motivation and inclusivity. Conversely, the continued reliance on NMIMs, such as chalkboard illustrations and textbook reading, restricts learners to passive observation, limiting their ability to recall and apply knowledge meaningfully (Bada & Olusegun, 2015). Despite evidence suggesting that MIMs can strengthen foundational learning, their application in Nigerian classrooms remains limited due to inadequate teacher preparation, lack of materials, and insufficient emphasis in biology curricula. Moreover, few empirical studies have examined their specific impact on students' lower-order thinking in genetics, particularly in northern Nigeria. Addressing this gap is essential to improving students' understanding of basic genetics concepts and to building the cognitive foundation necessary for higher-level reasoning in science.

This study therefore investigates the effect of manipulative instructional materials on secondary school students' lower-order thinking skills (LOTS) in genetics in Sokoto State, Nigeria, with gender also considered as a variable of interest.

### Statement of the Problem

Performance reports from the West African Examinations Council (WAEC, 2015–2021) and the National Examinations Council (NECO, 2010–2015) have persistently shown that Nigerian secondary school students exhibit poor achievement in genetics, particularly in questions requiring the recall, comprehension, and application of basic concepts. Many students are unable

to correctly define genetic terms, explain Mendelian laws, or apply the principles of inheritance to solve simple monohybrid and dihybrid cross problems. These deficiencies reflect weaknesses in lower-order thinking skills (LOTS), which are foundational to deeper understanding and problem-solving in science. When students fail to master LOTS, they struggle to progress to higher-order thinking tasks such as analysis, evaluation, and synthesis.

The problem is further compounded by the predominant reliance on non-manipulative instructional materials (NMIMs) including textbooks, chalkboards, and static charts which emphasize teacher-centered instruction. These materials, while adequate for content presentation, rarely provide opportunities for learners to actively engage with content or construct their own understanding. Consequently, learning remains largely passive, emphasizing rote memorization over comprehension and application. This situation limits students' ability to transfer knowledge or relate classroom experiences to real-life biological phenomena.

By contrast, manipulative instructional materials (MIMs) such as chromosome models, Punnett square kits, and gene interaction boards offer learners hands-on opportunities to observe, experiment, and visualize abstract genetic processes. Through direct interaction, students can more easily recall key concepts, comprehend their interrelationships, and apply them in practical contexts. Despite these benefits, the use of MIMs in teaching genetics remains minimal in most Nigerian secondary schools due to inadequate teacher training, limited resources, and a lack of policy emphasis on activity-based instruction.

This study, therefore, seeks to examine the effect of manipulative instructional materials on secondary school students' lower-order thinking skills in genetics in Sokoto State, Nigeria, with attention to gender as a moderating variable.

### Objectives of the Study

The study is designed to:

1. Compare the lower-order thinking of secondary school students taught genetics using manipulative instructional materials (MIMs) and

those taught using non-manipulative instructional materials (NMIMs).

2. Compare the lower-order thinking of male and female secondary school students taught genetics using manipulative instructional materials (MIMs) in Sokoto State, Nigeria.

### Research Hypotheses

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

**H<sub>01</sub>:** There is no significant difference in the pretest lower-order thinking scores of students taught genetics using manipulative instructional materials and those taught using non-manipulative instructional materials.

**H<sub>02</sub>:** There is no significant difference in the posttest lower-order thinking scores of students taught genetics using manipulative instructional materials and those taught using non-manipulative instructional materials.

**H<sub>03</sub>:** There is no significant difference in the lower-order thinking of male and female students taught genetics using manipulative instructional materials.

### Methodology

This study adopted a pretest–posttest quasi-experimental design. The design was appropriate because it allowed comparison of two instructional strategies, involving the use of Manipulative Instructional Materials (MIMs) for one group and Non-Manipulative Instructional Materials (NMIMs) for other group. The population of the study comprised all Senior Secondary School Three (SS3) biology students in public secondary schools in Sokoto State, Nigeria. From this population, a sample size 378 ascertained using research advisor table. participants were drawn using a multistage sampling, purposive sampling and proportionate sampling technique. The multistage and purposive sampling techniques were used while selecting educational zones and schools used in this study. This resulted to the selection of four public secondary schools from two zones. From these schools, two each were assigned to experimental and control groups. Proportionate random sampling was finally used to select students from the schools and also

assigned these school to either the Experimental Group (taught using MIMs) or the Control Group (taught using NMIMs). Furthermore, 189 students were assigned each group.

A pretest using the Genetics Lower-Order Thinking Test (GLOTT) was administered to all participants prior to treatment. The pretest assessed students' ability to recall, understand, and apply basic genetic concepts in accordance with Bloom's Revised Taxonomy. The pretest scores were not used to exclude students but to establish baseline equivalence between the groups and confirm that participants exhibited comparable lower-order thinking skills before the commencement of treatment. The Experimental Group was taught genetics using manipulative instructional materials through guided hands-on activities. Students worked with DNA and chromosome models to identify gene locations and chromosome behavior. Punnett square manipulatives were used to physically represent alleles during monohybrid and dihybrid crosses, allowing students to arrange and rearrange allele combinations. Students manipulated these materials individually and in small groups under the teacher's guidance, with the teacher facilitating discussions, correcting misconceptions, and linking activities to theoretical genetic principles. The Control Group, on the other hand, was taught using non-manipulative instructional materials such as charts and diagrams of the DNA and chromosome and, also using the chalkboard to illustrate monohybrid and Punnett square crosses. Both groups were taught by the same teacher to control for teacher-related effects, and the treatment lasted six weeks, covering identical topics in genetics.

The Genetics Lower-Order Thinking Test (GLOTT), was used to assess students' ability to recall, comprehend, and apply genetic concepts. The GLOTT consisted of 40 multiple-choice items covering topics such as Mendelian inheritance, Punnett squares, and genetic terminologies. The instrument was validated by experts in biology education and measurement and evaluation to ensure content and construct validity. A test-retest reliability procedure yielded a coefficient of 0.81 using the Pearson Product Moment Correlation (PPMC), indicating high reliability and consistency. Lower-order thinking skills were operationalized based on Bloom's Revised Taxonomy, focusing on remembering, understanding, and applying. Items assessing remembering required students to recall genetic terms and definitions, understanding was assessed through explanation of concepts and interpretation of inheritance patterns, and applying involved solving monohybrid and dihybrid cross problems using learned principles. Data collected were analyzed using descriptive and inferential statistics. Means and standard deviations were used to answer the research questions, while independent samples t-tests were employed to test the null hypotheses at the 0.05 level of significance. A pretest comparison of the two groups was conducted to confirm homogeneity before treatment, ensuring that any observed posttest differences could be attributed to the instructional treatments rather than pre-existing cognitive differences.

## RESULTS

**H<sub>01</sub>:** There is no significant difference in the pretest lower-order thinking scores of students taught genetics using manipulative instructional materials and those taught using non-manipulative instructional materials.

**Table 1 Pretest Homogeneity of Lower-Order Thinking Scores**

Group	N	Mean	SD	df	t-value	p-value	Decision
Experimental	189	15.20	3.68	376	13.12	< .001	Significant
Control	189	11.39	1.54				

The results in Table 1 show the pretest performance of the Experimental and Control Groups on lower-order thinking skills in genetics. The Experimental Group recorded a mean score of 15.20 (SD = 3.68), while the Control Group had a mean score of 11.39 (SD = 1.54). The independent samples t-test yielded a t-value of 13.12 with and a p-value < .001, indicating a statistically significant difference. This suggests that the

Experimental Group had a higher baseline performance than the Control Group prior to the intervention.

**H<sub>02</sub>:** There is no significant difference in the posttest lower-order thinking scores of students taught genetics using manipulative instructional materials and those taught using non-manipulative instructional materials.

**Table 2 Posttest Comparison of Lower-Order Thinking Scores**

Group	N	Mean	SD	df	t-value	p-value	Decision
Experimental	189	32.38	3.37	376	26.25	< .001	Reject
Control	189	25.37	1.47				

The results in Table 2 present the posttest performance of students in the Experimental and Control Groups on lower-order thinking skills in genetics. Students in the Experimental Group recorded a mean score of 32.38 (SD = 3.37), while those in the Control Group had a mean score of 25.37 (SD = 1.47). The independent samples t-test yielded a t-value of 26.25 with and a p-value < .001. This indicates a highly statistically

significant difference in favor of the Experimental Group, showing that manipulative instructional materials substantially improved students' lower-order thinking skills compared to conventional instruction.

**H<sub>03</sub>:** There is no significant difference in the lower-order thinking of male and female students taught genetics using manipulative instructional materials.

**Table 3 Gender Comparison in Experimental Group**

Group	N	Mean	SD	df	t-value	p-value	Decision
Male	89	32.02	3.63	173	-1.37	.172	Fail to
Female	100	32.70	3.10				

The results in Table 3 present the performance of male and female students in the Experimental Group on lower-order thinking skills in genetics. Male students recorded a mean score of 32.02 (SD = 3.63), while female students had a mean score of 32.70 (SD = 3.10). The mean difference of 0.68 shows a marginal advantage in favor of the female students. The independent samples t-test yielded a t-value of -1.37 with and a p-value of 0.172, which is not statistically

significant at the 0.05 level. This result indicates that the use of manipulative instructional materials had a similar effect on the lower-order thinking skills of both male and female students. Accordingly, the null hypothesis for gender differences was not rejected.

### Discussion of Findings

The discussion of findings is presented in line with the results obtained from the study. The discussion highlights the

effects of manipulative instructional materials (MIMs) on secondary school students' lower-order thinking skills in genetics and examines the role of gender in students' performance.

The findings of the study revealed a statistically significant difference in the lower-order thinking scores of students taught genetics using manipulative instructional materials and those taught using non-manipulative instructional materials. Students who were exposed to manipulative instructional materials recorded higher mean scores than their counterparts taught with conventional instructional materials. This indicates that manipulative instructional materials significantly enhanced students' ability to recall, understand, and apply genetic concepts more effectively than traditional instructional approaches.

The improvement observed in students' lower-order thinking skills can be attributed to the interactive and experiential nature of manipulative instructional materials, which allow learners to engage directly with abstract genetic concepts. The use of DNA models, chromosome kits, Punnett square manipulatives, and dihybrid cross boards promoted active participation and enabled students to visualize and manipulate genetic processes that are often difficult to comprehend through verbal explanations alone. This finding is consistent with constructivist learning theory, which emphasizes that learners develop deeper understanding when they actively construct knowledge through hands-on experiences (Schunk, 2020; Mupa & Chinooneka, 2023).

In addition, the finding can be explained within the framework of Bloom's Revised Taxonomy, which identifies remembering, understanding, and applying as foundational cognitive processes necessary for meaningful learning (Anderson & Krathwohl, 2001). Manipulative instructional materials supported students in recalling genetic terminologies, explaining inheritance patterns, and applying genetic principles to problem-solving situations. Recent studies have shown that instructional strategies that target these lower-order cognitive processes significantly enhance conceptual clarity and retention in science

subjects (Akpan & Beard, 2021; Yusuf & Afolabi, 2022).

The findings of this study are consistent with recent empirical research. Bello, Sadiq, and Musa (2021) reported that students taught biology concepts using manipulative instructional materials demonstrated significantly higher achievement and conceptual understanding than those taught using conventional methods. Similarly, Moyer-Packenham et al. (2022) found that manipulative-based instruction improves cognitive engagement by transforming abstract scientific concepts into tangible learning experiences. These findings collectively reinforce the effectiveness of manipulative instructional materials in improving students' lower-order thinking skills in genetics.

Conversely, students taught using non-manipulative instructional materials such as textbooks, chalkboards, and teacher-centered explanations recorded relatively lower performance. This may be due to the passive nature of such instructional methods, which often emphasize rote memorization and limit students' active involvement in the learning process. Recent studies have noted that traditional instructional approaches are less effective in promoting meaningful understanding and application of scientific concepts, particularly in abstract areas such as genetics (OECD, 2019; Gambari & Yusuf, 2021).

The findings further revealed that male and female students taught genetics using manipulative instructional materials performed similarly in terms of lower-order thinking skills. Although female students recorded a slightly higher mean score than male students, the difference was not statistically significant. This suggests that manipulative instructional materials provide equal learning opportunities for both genders and support inclusive classroom participation. This outcome implies that the effectiveness of manipulative instructional materials is not influenced by gender. The hands-on and learner-centered nature of these materials allows all students to engage meaningfully with instructional tasks regardless of gender. This finding aligns with recent studies which reported that gender differences in science

achievement tend to diminish when activity-based and student-centered instructional strategies are employed (Brotman & Moore, 2020; Yusuf, Gambari, & Olumorin, 2021). Consequently, manipulative instructional materials can be regarded as effective tools for promoting gender equity in biology classrooms.

### Summary of the Discussion

The discussion of findings revealed that manipulative instructional materials significantly enhanced secondary school students' lower-order thinking skills in genetics. Students exposed to manipulative instructional materials demonstrated superior ability to recall, understand, and apply genetic concepts compared to those taught using non-manipulative instructional materials. This improvement was attributed to the interactive and experiential nature of manipulative instructional materials, which transformed abstract genetic concepts into concrete and meaningful learning experiences. The findings were explained using constructivist learning theory and Bloom's Revised Taxonomy, both of which emphasize active engagement and progressive cognitive development as essential components of effective learning.

The discussion also revealed that the use of manipulative instructional materials had a similar effect on the lower-order thinking skills of male and female students. Although slight differences in mean scores were observed, these differences were not statistically significant, indicating that manipulative instructional materials provide equitable learning opportunities across gender. Overall, the discussion established that manipulative instructional materials are effective, inclusive, and suitable for improving foundational cognitive skills in genetics at the secondary school level.

### Conclusions

Based on the findings of this study, it is concluded that manipulative instructional materials are effective tools for improving secondary school students' lower-order thinking skills in genetics. The use of hands-on instructional materials such as DNA models, chromosome kits, and Punnett square manipulatives significantly improved students' ability to recall,

comprehend, and apply genetic concepts when compared to conventional instructional methods. The study also concludes that manipulative instructional materials are gender-neutral, as both male and female students benefited equally from their use. Consequently, manipulative instructional materials can be regarded as valuable resources for enhancing conceptual understanding and promoting inclusive science education in secondary schools.

### Recommendations

Based on the findings and conclusions of this study, the following recommendations are made:

1. Biology teachers should adopt the use of manipulative instructional materials in the teaching of genetics to enhance students' lower-order thinking skills and promote meaningful learning.
2. School administrators and educational policymakers should ensure the provision and adequate supply of manipulative instructional materials in secondary schools to support effective biology instruction.
3. Teacher training institutions and professional development programs should emphasize the design, selection, and effective use of manipulative instructional materials to equip teachers with practical instructional skills.
4. Curriculum planners should integrate manipulative-based instructional strategies into the biology curriculum, particularly for abstract topics such as genetics.
5. Future researchers should replicate this study using different science subjects, educational levels, or research designs to further validate the effectiveness of manipulative instructional materials on students' cognitive development.

### Reference

- Akpan, J. P., & Beard, L. A. (2021). Using manipulatives to enhance students' conceptual understanding in science classrooms. *Journal of Science Education and Technology*, 30(4), 512–525. <https://doi.org/10.1007/s10956-021-09901-3>



- Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.
- Arop, F. O. (2015). Instructional materials and students' academic achievement in biology. *International Journal of Educational Research*, 3(2), 45–52.
- Bada, S. O., & Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education*, 5(6), 66–70.
- Bello, S., & Aminu, A. (2019). Effects of manipulative instructional materials on students' achievement in biology. *Journal of Science Teachers Association of Nigeria*, 54(2), 123–132.
- Bello, S., Sadiq, A. M., & Musa, M. A. (2021). Activity-based instruction and secondary school students' achievement in biology. *African Journal of Educational Research*, 25(1), 89–101.
- Brotman, J. S., & Moore, F. M. (2020). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching*, 57(4), 529–555. <https://doi.org/10.1002/tea.21610>
- Gambari, A. I., & Yusuf, M. O. (2021). Innovative instructional strategies and students' learning outcomes in science education. *Contemporary Educational Technology*, 13(1), ep289. <https://doi.org/10.30935/cedtech/9605>
- Krathwohl, D. R. (2022). Revisiting Bloom's taxonomy: Implications for teaching and assessment. *Educational Psychology Review*, 34(2), 987–1005. <https://doi.org/10.1007/s10648-021-09634-1>
- Moyer-Packenham, P. S., & Westenskow, A. (2019). Effects of virtual manipulatives on student achievement and mathematics learning. *International Journal of Research in Education and Science*, 5(1), 35–50.
- Moyer-Packenham, P. S., Litster, K., Bullock, E. P., & Shumway, J. F. (2022). The role of manipulatives in developing conceptual understanding. *Educational Studies in Mathematics*, 110(2), 221–243. <https://doi.org/10.1007/s10649-021-10104-7>
- Mupa, P., & Chinooneka, T. I. (2023). Constructivist instructional strategies and learners' cognitive engagement in science classrooms. *International Journal of Learning, Teaching and Educational Research*, 22(3), 112–128.
- OECD. (2019). *Innovating education and educating for innovation: The power of digital technologies and skills*. OECD Publishing. <https://doi.org/10.1787/9789264313124-en>
- Oyelekan, O. S., & Bello, G. (2019). Instructional materials and effective teaching of science in Nigerian secondary schools. *Journal of Educational Practice*, 10(18), 45–52.
- Schunk, D. H. (2020). *Learning theories: An educational perspective* (8th ed.). Pearson Education.
- UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. UNESCO Publishing.
- West African Examinations Council. (2015–2021). *Chief examiners' reports on biology*. WAEC.
- Yusuf, M. O., & Afolabi, A. O. (2022). Student-centered learning approaches and academic achievement in science. *Journal of Educational Technology & Society*, 25(2), 98–110.
- Yusuf, M. O., Gambari, A. I., & Olumorin, C. O. (2021). Gender equity and innovative teaching strategies in science education. *Journal of Research in STEM Education*, 5(1), 34–47.