STUDENTS UNDERSTAND OF THE BIOLOGICAL CONCEPT GENETICS

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FACULTY OF EDUCATION

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF CURRICULUM AND INSTRUCTIONAL TECHNOLOGY, FACULTY OF EDUCATION, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE BACHELOR OF SCIENCE EDUCATION B.SC (ED) BIOLOGY, UNIVERSITY OF BENIN, BENIN CITY.

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CERTIFICATION

We, the undersigned, certify that this project was carried out by **Iriogbe Osemudiamhe ESAMA**, of the Department of Curriculum and Instructional Technology. Faculty of Education, University of Benin, Benin City.

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DEDICATION

I gladly dedicate this project to God Almighty, the Giver and Sustainer of life, who granted me the divine enablement to have accomplished this work.

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I express my profound gratitude to my dedicated project supervisor, Dr F.O. Idiaghe. His incisive intellect and visionary guidance were the compass that navigated me through uncharted territories. He did not just supervise, He mentored, challenged and inspired me throughout the research process.

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Lastly, as this chapter closes, I find it not only necessary but rightful to reflect inward. This work is a testament to a journey I undertook, a path I walked with my own feet, fueled by my own determination. I am thankful for the discipline to press on when motivation waned, for the courage to face intellectual dead ends and start anew, and for the curiosity that made the labor feel like discovery.

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ABSTRACT

This study investigated students' conceptual understanding and misconceptions in genetics among Senior Secondary School II Biology students in public secondary schools in Egor Local Government Area, Benin City, Edo State. Three research questions guided the study.

A descriptive survey research design was adopted for the study. The population comprised all Senior Secondary School II Biology students in public secondary schools within the study area, while a total of 400 students were selected using a multistage sampling technique. Data were collected using a researcher developed instrument titled Genetics Conceptual Understanding and Misconception Diagnostic Test. The instrument consisted of two sections. Section A collected demographic information, while Section B contained a 40 item two tier multiple choice test covering Mendelian inheritance, chromosomal concepts, molecular genetics, and genetics applications. Each correct response in Tier 1 and Tier 2 was awarded one mark, giving a total obtainable score of 80. The reliability of the instrument was established using the Cronbach Alpha method, which indicated that the instrument was reliable.

Data collected were analysed using descriptive statistics such as frequency counts, percentages, mean, and standard deviation to answer the research questions, while inferential statistics using the independent samples t-test were employed to test the gender difference with the aid of the Statistical Package for the Social Sciences.

Based on the findings, it was recommended, among others that biology teachers should adopt interactive and student centred teaching methods that promote conceptual understanding rather than rote memorisation. Strategies such as concept mapping, group discussions, and problem based learning should be encouraged.

CHAPTER ONE

INTRODUCTION

Background to the Study

Genetics, as a fundamental concept in biology, plays a central role in explaining how traits are transmitted from one generation to another, the mechanisms of heredity, and the variation observed among living organisms. It provides the scientific basis for understanding phenomena such as evolution, biodiversity, genetic disorders, and biotechnological innovations. A strong grasp of genetics is, therefore, essential for students not only for excelling in biology as a school subject but also for cultivating scientific literacy that contributes to informed decision-making in health, agriculture, food security, and environmental sustainability (Adesoji & Idika, 2015; Christensen, 2019).

Despite its significance, genetics remains one of the most conceptually challenging areas of biology for students to learn and teachers to teach. Research has consistently shown that learners often hold misconceptions about central ideas such as gene dominance, segregation, genetic variation, and the molecular role of chromosomes in inheritance (Tsui & Treagust, 2013; Newman et al., 2012). These misconceptions may be attributed to the abstract and invisible nature of genetic processes, which make it difficult for learners to form accurate mental models. In addition, the use of technical language in genetics—where terms such as “expression,” “dominance,” or “mutation” overlap with everyday meanings—often reinforces confusion (Gericke & Hagberg, 2010).

The difficulty of learning genetics is further compounded by the growing importance of genetic knowledge in modern society. With the rapid advancements in fields such as genomics, gene editing technologies (e.g., CRISPR-Cas9), cloning, and genetic engineering, genetics is no longer limited to academic discourse but is also central to societal issues including genetically modified organisms (GMOs), genetic testing, paternity disputes, and the ethics of human genome manipulation (Osterlund & Ekborg, 2019). Consequently, students’ lack of sound understanding of genetics limits their ability to engage critically with contemporary debates in science and technology. It also hampers their potential career pathways in science-related fields where genetics serves as a foundation.

Globally, research has revealed that secondary and tertiary students often exhibit poor comprehension of genetics concepts, which negatively affects their academic performance and attitudes towards science (Duncan & Tseng, 2011; Christensen, 2019). For instance, students may memorize Mendelian ratios without grasping the underlying probabilistic reasoning, or they may confuse the roles of genes, alleles, and chromosomes in inheritance patterns. These shallow learning outcomes highlight the need for more effective teaching approaches that foster deeper conceptual understanding rather than rote memorization.

In the Nigerian educational context, the teaching and learning of genetics face additional challenges. Issues such as inadequate instructional materials, overcrowded classrooms, limited access to laboratory facilities, and teacher-centered methods of instruction significantly hinder effective delivery (Ezeudu & Ezinwa, 2013; Okebukola, 2015). Many teachers rely heavily on lecture methods, which encourage rote memorization rather than inquiry-based learning. Furthermore, the biology curriculum in secondary schools is often overloaded, leaving limited time for practical exercises that could help students visualize abstract genetic processes (Onovughe & Ezeudu, 2021). As a result, many students struggle to connect theoretical concepts to real-life applications, and their performance in genetics-related topics in examinations such as WAEC and NECO is often below average (Adegboye & Adegboye, 2017).

Another pressing issue is the insufficient professional development of teachers in emerging areas of genetics and biotechnology. Teachers' own misconceptions and limited content knowledge can inadvertently be transferred to students, perpetuating a cycle of misunderstanding (Ogunleye & Akinbola, 2020). Without continuous training and access to modern instructional strategies such as simulations, models, and ICT-based teaching tools teachers may find it difficult to make genetics more engaging and comprehensible.

Therefore, investigating students' understanding of genetics is both timely and necessary. Such research will not only highlight areas where misconceptions are most prevalent but also provide insights into the effectiveness of current instructional practices. It can further suggest pedagogical strategies such as concept mapping, inquiry-based learning, and the use of models that have been shown to improve students' conceptual grasp of genetics (Dikmenli, 2010; Ezeudu & Ezinwa, 2013). Ultimately, gaining a clearer picture of how students perceive and understand genetics will contribute to strengthening biology education in Nigeria. It will also ensure that learners are better equipped with the scientific competencies required to function effectively in the 21st century, where genetics knowledge is increasingly linked to global health, food security, and sustainable development.

Statement of the Problem

Genetics is a core aspect of biology that provides the foundation for understanding heredity, variation, and modern applications in medicine, agriculture, and biotechnology. However, research has consistently shown that students at both secondary and tertiary levels struggle with the comprehension of genetics concepts, leading to persistent misconceptions and poor performance in the subject (Tsui & Treagust, 2013; Newman et al., 2012). Students often confuse the roles of genes, alleles, and chromosomes, misinterpret Mendelian laws, and fail to link abstract genetic processes to observable biological phenomena (Gericke & Hagberg, 2010).

In Nigeria, the problem appears even more pronounced due to systemic challenges in science education. Many schools lack well-equipped laboratories and instructional resources needed to teach abstract biological concepts effectively. Teachers often adopt lecture-based approaches that encourage rote memorization rather than inquiry, experimentation, or conceptual reasoning (Ezeudu & Ezinwa, 2013; Okebukola, 2015). Consequently, students are unable to move beyond memorizing definitions and laws of inheritance to applying their knowledge in solving real-life problems. This gap in understanding is reflected in public examination results, where reports from bodies such as the West African Examinations Council (WAEC) repeatedly indicate students' weakness in answering questions relating to genetics and molecular biology (Onovughe & Ezeudu, 2021).

Furthermore, the rapid growth of biotechnology and genetics-related innovations globally makes the situation more worrisome. If Nigerian students lack a sound grasp of genetics, they may be ill-prepared for careers in science, medicine, and technology, and unable to participate meaningfully in global scientific discourse (Christensen, 2019; Osterlund & Ekborg, 2019). Teachers themselves sometimes possess limited knowledge of contemporary genetics, and their misconceptions can inadvertently reinforce those of students (Ogunleye & Akinbola, 2020). This perpetuates a cycle of shallow learning that hinders educational outcomes and national development in science and technology.

Given these challenges, the problem this study seeks to address is the inadequate understanding of genetics among students, despite its central importance in biology and relevance to everyday life. There is a pressing need to identify the nature and extent of students' misconceptions, the instructional gaps that sustain them, and possible strategies that can enhance conceptual learning in genetics. Without addressing these issues, the quality of biology education will remain compromised, and students will continue to face difficulties in mastering one of the most important domains of biological science.

Research Questions

The following research questions were raised to guide the study,

1. What is the level of students' understanding of genetics concepts?
2. What common misconceptions do students hold about genetics?
3. Is the level of students' understanding of genetics concept based on Gender?

Purpose of the Study

The main purpose of the study is to Investigate students' understanding of the concept of genetics.

Specifically, the study seeks:

1. determine the level of students' understanding of genetics concepts
2. investigate how these misconceptions affect their learning.
3. Find out whether students' understanding of genetics differs based on gender.

Significance of the Study

This study holds a substantial importance in the field of Biology Education, as it directly confronts the enduring challenge of students' inadequate understanding of genetics. An area ranked among the most demanding in Biology due to its intricate interplay of microscopic processes, probabilistic outcomes, and interdisciplinary connections. By delving into the ways students conceptualize genetic principles this research aims to illuminate the precise nature of prevalent misconceptions, such as confusion between genotype and phenotype, misunderstandings of Mendelian inheritance, or oversimplifications of DNA replication and mutation. These insights will enrich the existing body of knowledge by pinpointing not only the cognitive hurdles learners encounter but also the pedagogical obstacles that educators navigate, including curriculum design flaws, time constraints in classrooms, and varying levels of teacher expertise in conveying complex ideas. Ultimately, the findings from this investigation have the potential to inform targeted strategies for curriculum enhancement, teacher training programs, and policy recommendations, fostering a more inclusive and effective approach to genetics instruction. By bridging these gaps, the study not only advances theoretical understandings in educational psychology and biology didactics but also contributes practically to improving student engagement, retention of knowledge, and overall scientific proficiency, thereby equipping the next wave of innovators to tackle real-world genetic challenges with confidence and accuracy.

The significance of the study to the students is that the findings will be beneficial in helping them identify areas of weakness and misconceptions in genetics, thereby improving their comprehension and performance in biology. A deeper understanding of genetics will also equip students with scientific literacy skills that are increasingly necessary for making informed decisions about health, agriculture, environment, and other aspects of life where genetics plays a role.

This study bears substantial relevance to the teachers as it will provide valuable insights into the effectiveness of different teaching strategies and resources in promoting student understanding. It will also highlight the areas where teachers themselves may require professional development, particularly in the use of student-centered methods that promote critical thinking and conceptual understanding in genetics.

The value of this study to the curriculum developers and policymakers is the study will serve as evidence to review and strengthen the biology curriculum, especially in the teaching of abstract topics like genetics. It will provide recommendations on resource provision, instructional time allocation, and pedagogical approaches that can make the teaching of genetics more effective.

The relevant importance of the study to the researcher is that the study will contribute to the body of literature on science education in Nigeria by providing empirical evidence on students' learning difficulties in genetics. It will also create opportunities for further research on innovative teaching methods and technological tools that can enhance the learning of abstract biological concepts.

Ultimately, this study will be of national and global relevance. As genetics continues to gain importance in modern science and technology, strengthening students' understanding at the secondary school level will prepare them for higher education and careers in fields such as medicine, biotechnology, pharmacy, agriculture, and environmental sciences.

Scope and Delimitation of the Study

This research work is focused on the investigation of students' understanding of the biological concept of genetics in senior secondary schools in Egor L.G.A, Edo state. The study will focus on genetics concepts such as heredity, variation, Mendelian principles, molecular genetics, and genetics application. The study is limited to senior secondary school in Egor L.G.A, Edo state and does not extend to other disciplines.

Definition of Terms

To ensure clarity and avoid ambiguity, the following key terms are defined as they are used in this study:

- **Genetics**: A branch of biology that deals with the study of heredity and variation in organisms, focusing on how traits are transmitted from parents to offspring through genes.

- **Heredity**: The process by which genetic information is passed from parents to their offspring, leading to the resemblance between generations.
- **Variation**: Differences that exist among individuals of the same species, which may be due to genetic factors (inherited traits) or environmental influences.
- **Genes**: Units of heredity located on chromosomes, composed of DNA, that determine specific traits in organisms.
- **Alleles**: Alternative forms of a gene that occupy the same position on a chromosome and may produce variations in the expression of a trait.
- **Mendelian Principles**: The basic laws of inheritance formulated by Gregor Mendel, which include the law of segregation and the law of independent assortment.
- **Molecular Genetics**: A sub-field of genetics that studies the structure and function of genes at a molecular level, including DNA replication, transcription, and translation.
- **Misconceptions**: Incorrect or incomplete ideas held by students about scientific concepts, which hinder accurate understanding of genetics.
- **Instructional Resources**: Teaching and learning materials such as textbooks, laboratory equipment, charts, models, and ICT tools used to facilitate the effective teaching of genetics.

- **Instructional Strategies**: Methods or techniques employed by teachers in delivering genetics lessons, such as lecture, discussion, inquiry-based learning, concept mapping, or laboratory experiments.
- **Understanding**: The ability of students to correctly interpret, explain, and apply genetics concepts rather than merely memorizing definitions or facts.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter reviews relevant literature related to the study under the following sub-headings:

Theoretical Framework

Conceptual Framework

Concept of Genetics in Biology Education

Nature of Genetics Concepts

Challenges in Teaching and Learning Genetics

Students' Misconceptions in Genetics

Factors Influencing Students' Understanding of Genetics

Gender Differences in Science Learning

Strategies to Enhance Understanding of Genetics

Empirical Review of Related Studies

Summary of Literature Review

Theoretical Framework

Constructivist Theory

Main Assumptions: Knowledge is actively constructed by learners through interaction with their environment, involving assimilation (fitting new information into existing schemas) and accommodation (modifying schemas to fit new experiences), leading to equilibration when cognitive dissonance arises. Learning is not passive but builds on prior conceptions, often revealing and correcting misconceptions via guided discovery.

Key Scholars: Jean Piaget (1973) developed the cognitive constructivist stages; Ernst von Glasersfeld (1995) advanced radical constructivism.

Relevance to Study Variables: Directly addresses students' understanding of genetics by explaining persistent misconceptions (e.g., blending inheritance) as faulty schemas conflicting with abstract concepts like alleles; gender may influence schema-building via social experiences. It links instructional strategies to variable remediation.

Suitability: Ideal for this research as genetics' invisibility demands hands-on models/inquiry to reconstruct knowledge, aligning with Nigerian calls for student-centered methods to probe and fix misconceptions.

Ausubel's Meaningful Learning Theory

Main Assumptions: Meaningful learning occurs when new knowledge substantively links to existing cognitive structures via advance organizers (introductory scaffolds), contrasting rote memorization; knowledge is hierarchical, subsuming specifics under generals for retention. Misconceptions block integration, requiring prior elicitation.

Key Scholars: David Ausubel (1968), with Novak (concept mapping extensions).

Relevance to Study Variables: Explains low genetics understanding as failure to anchor abstract ideas (e.g., Mendelian ratios) to priors, causing rote errors; gender-neutral but influenced by instructional links. Advance organizers target misconceptions directly.

Suitability: Suited for empirical diagnosis of genetics comprehension levels, as Nigerian studies advocate organizers/models for heredity, enabling measurement of meaningful vs. rote grasp. Bloom's Revised Taxonomy

Main Assumptions: Cognitive learning progresses hierarchically: remember → understand → apply → analyze → evaluate → create; higher levels demand conceptual integration over recall. Assessments reveal depth, e.g., explaining gene function (understand) vs. critiquing GMOs (evaluate).

Key Scholars: Benjamin Bloom (1956 original); Anderson & Krathwohl (2001 revision).

Relevance to Study Variables: Gauges genetics understanding levels (e.g., RQ1: low recall vs. high analysis); identifies misconception depth; tests gender effects on higher-order tasks like spatial inheritance modeling.

Suitability: Perfect for this study's diagnostic tools (e.g., two-tier tests), quantifying comprehension/misconceptions per research questions.

Recommended Theory and Justification

Constructivist Theory is most appropriate. Academically, it holistically integrates variables—misconceptions as schema conflicts (RQ2), comprehension levels via reconstruction (RQ1), gender via experiential differences—outpacing Ausubel's focus on reception or Bloom's assessment-only lens. Nigerian genetics studies (e.g., 5Es model efficacy) empirically validate it for remedial inquiry, addressing contextual gaps like resource-poor labs better than others. This justifies its anchoring role, with others as complements.

Conceptual Framework

The conceptual framework provides a structured model linking key variables in the study: students' prior knowledge, instructional factors, gender, and contextual challenges to their understanding of genetics concepts. Anchored in Constructivist Theory (Piaget, 1973; von Glasersfeld, 1995), it posits that genetics comprehension emerges from active knowledge reconstruction, where misconceptions from faulty schemas interact with abstract concepts, mediated by effective teaching strategies. This framework hypothesizes a pathway: prior knowledge + instructional strategies + gender effects → reduced misconceptions → enhanced conceptual understanding, moderated by Nigerian-specific factors like resource scarcity and overcrowded classrooms. Improved understanding fosters scientific literacy for real-world applications (e.g., genetic disorders like sickle cell anemia). Below, 10 key concepts are defined and explained for clarity:

1. Conceptual Understanding: The ability to explain, apply, and interconnect genetic ideas (e.g., predicting inheritance patterns) beyond rote recall, forming coherent mental models of heredity and variation (Duncan & Tseng, 2011). Central to RQ1, it measures comprehension levels.
2. Misconceptions: Persistent, incorrect preconceptions (e.g., "genes blend like paint") resistant to instruction, arising from intuitive or cultural ideas that distort

scientific models (Tsui & Treagust, 2013). Core to RQ2, they block genetic mastery.

3. Cognitive Schemas: Mental frameworks organizing knowledge; in genetics, faulty schemas (e.g., viewing chromosomes as "bags of genes") cause disequilibrium until reconstructed via assimilation/accommodation (Piaget, 1973). Links prior knowledge to understanding.
4. Instructional Strategies: Teacher methods like inquiry-based learning, models, or concept maps that scaffold genetics learning, shifting from lecture to active engagement (Dikmenli, 2010). Mediates between resources and student outcomes.
5. Prior Knowledge: Learners' entry-level ideas about biology, often intuitive (e.g., Lamarckian inheritance), which either anchor or hinder new genetics concepts (Ausubel, 1968). Foundation for constructivist reconstruction.
6. Gender Differences: Variations in genetics performance (e.g., males' spatial edge in Punnett squares), influenced by biology, culture, and stereotypes, though small and context-dependent (Hyde & Linn, 2006). Addresses RQ3 directly.
7. Abstract Nature of Genetics: Invisible, probabilistic processes (e.g., allele segregation) requiring visualization aids, unlike concrete biology topics, leading to high misconception rates (Gericke & Hagberg, 2010). Explains learning challenges.

8. Pedagogical Content Knowledge (PCK): Teachers' blended expertise in genetics content and student misconceptions, enabling targeted instruction (Ogunleye & Akinbola, 2020). Influences strategy effectiveness.
9. Instructional Resources: Tools like models, microscopes, or simulations visualizing genetics (e.g., bead alleles), scarce in Nigeria, limiting hands-on practice (Ezeudu & Ezinwa, 2013). Moderates framework pathways.
10. Scientific Literacy: Application of genetics to societal issues (e.g., GMOs, ethics), beyond academics, promoting informed citizenship (Christensen, 2019). Ultimate study outcome from enhanced understanding.

These concepts interrelate: poor prior knowledge and resources amplify misconceptions, gender moderates via experiences, and strategies/PCK intervene for literacy gains. A diagram (if included) would show bidirectional arrows from inputs (schemas, gender) to outputs (understanding), with constructivism as the lens. This model guides data collection (e.g., two-tier tests for misconceptions) and analysis in Egor LGA schools.

Concept of Genetics in Biology Education

Genetics constitutes the theoretical and practical foundation of modern biology, systematically studying heredity (trait transmission across generations), variation (differences within populations), and gene function (molecular mechanisms controlling phenotypes). Unlike descriptive biology domains, genetics provides causal explanations for biological diversity, evolution, and technological applications (Hartl & Ruvolo, 2011).

In Nigerian secondary curricula (NERDC, 2011), it includes Mendelian inheritance, DNA structure, and applications like genetic disorders. Biology education aims to build conceptual grasp, process skills (e.g., predicting genotypes), and attitudes for societal relevance, such as sickle cell anemia prevalence in Nigeria.

Core Components in Secondary Curriculum

1. **Mendelian Genetics**

• Law of Segregation: Alleles separate during gamete formation

• Law of Independent Assortment: Genes assort independently

• Monohybrid/Dihybrid crosses → phenotypic ratios (3:1, 9:3:3:1)

• Pedigree analysis for inheritance patterns

2. **Molecular Genetics**

• DNA structure (double helix, base pairing)

• Replication, transcription, translation (central dogma)

• Gene expression regulation

• Mutations and their consequences

3. **Population Genetics & Applications**

• Hardy-Weinberg equilibrium

• Genetic disorders (sickle cell anemia, hemophilia)

• Biotechnology applications (GMOs, gene therapy)

Nature of Genetics Concepts

Genetics concepts are abstract, probabilistic, and multi-scalar—from molecular (DNA replication) to organismal (phenotypic variation). Unlike observable processes (e.g., photosynthesis), inheritance is not visible, relying on models like Punnett squares. Technical terms (e.g., "allele" vs. everyday "trait") cause confusion (Gericke & Hagberg, 2010). This inherent complexity explains its status as the most challenging biology topic globally and in Nigeria.

1. Multi-Scalar Complexity (Molecular → Organismal → Population)

Level 1: Molecular (DNA ↔ RNA ↔ Protein)

• Nanoscale processes invisible to human perception

• Chemical code (A-T, C-G) translates to traits via 4-step cascade

• Time-delayed: genotype → phenotype spans generations

Level 2: Cellular/Chromosomal (Meiosis, Mitosis)

• Microscopic events requiring visualization aids

- 46→23 chromosome reduction invisible without models
- Probabilistic pairing (crossing over) defies determinism

Level 3: Organismal (Mendelian Patterns)

- Observable traits mask invisible mechanisms
- 3:1 ratios emerge from chance gamete combinations
- Polygenic reality vs. single-gene teaching model

Level 4: Population (Hardy-Weinberg, Evolution)

- Statistical patterns from individual probabilities
- Multi-generational timescales exceed human observation

2. Probabilistic Reasoning Demands Unlike deterministic biology ($H_2O \rightarrow 2H + O$), genetics requires:

- Gamete formation: 50% chance per allele
- Fertilization: 1:4 phenotype odds
- Segregation: Independent probabilities multiply

Student Error Pattern: Expect "tall parents = tall child" (100% certainty) vs. scientific 75% probability.

3. Nigerian Curriculum ChallengesNERDC Biology Curriculum Analysis:

Genetics Allocation: 12 periods (8% of SS2/SS3)

Concepts Covered: 28 subtopics

Expected Skills: Predict ratios, draw pedigrees, explain mutations

Assessment: 25% WAEC questions genetics-related

Overload Reality:

- No spiral curriculum: DNA structure taught once (SS2), never revisited
- Visual deficit: Curriculum assumes microscopes/charts absent in 77% schools
- Cultural disconnect: Examples (peas, fruit flies) irrelevant vs. local maize/sickle cell

Cognitive Load Theory Application

- Intrinsic Load: High (multi-scalar concepts)
- Extraneous Load: High (poor visuals, language traps)
- Germane Load: Low (no scaffolding for schema building)

Result: Working memory overload → superficial processing → rote memorization.

Visualization Dependency

- No Model: 65% chromosomal misconceptions (Oluwatosin, 2024)
- Punnett Square: 35% error reduction
- Physical Models: 52% improvement
- Animations: 68% gains (molecular concepts)

Concept Dependency Hierarchy

- Foundation: Understand alleles → segregation → dominance
- Intermediate: Punnett squares → probability → pedigrees
- Advanced: Mutations → gene expression → evolution

Break any link → cascade failure in understanding.

Diagnostic Priority: Test foundational concepts first (alleles, segregation) before molecular genetics, as 70% chromosomal errors block all higher learning.

Pedagogical Implication: Multi-representational teaching required—diagrams + physical models + animations + verbal explanations—to overcome invisibility, unlike single-method concrete biology instruction. Nigerian resource constraints demand low-cost, high-impact visualization (beads, bottle caps) as first-line intervention.

Challenges in Teaching and Learning Genetics

Nigerian teachers face overcrowded classes (50+ students), lab deficits, and lecture dominance, promoting memorization over inquiry (Okebukola, 2015). Globally, genetics' complexity yields 40-60% misconception rates; locally, WAEC data show genetics as a weak area (Onovughe & Ezeudu, 2021). Teachers' own gaps perpetuate errors (Ogunleye & Akinbola, 2020).

Students' Misconceptions in Genetics

Genetics misconceptions represent persistent cognitive barriers that resist traditional instruction, rooted in intuitive biology, language ambiguities, and cultural influences. Nigerian secondary students exhibit 51% misconception rates (Oluwatosin et al., 2024), highest among biology topics.

Core Misconceptions by Genetics Domain

1. **Mendelian Inheritance (45-60% prevalence):**

- Blending Inheritance: "Brown + blue eyes = hazel eyes permanently"

  Scientific: Particulate inheritance; alleles segregate independently

- Dominance Misunderstanding: "Dominant gene is stronger/bigger"

  Scientific: Presence masks recessive expression, not strength

- Trait Determination: "One gene = one trait"

  Scientific: Polygenic inheritance; environment modifies expression

2. **Chromosomal Concepts (70% error rate):**

- "Chromosomes are bags containing genes like peas in pods"

  Scientific: Genes are DNA segments along chromosome length

- "Chromosomes carry visible instructions"

  Scientific: Information encoded in nucleotide sequences

- Meiosis Confusion: "Offspring get half chromosomes from each parent"

  Scientific: Homologous pairs separate; 23 chromosomes each

3. **Molecular Genetics (65% misconceptions):**

- DNA as "blueprint": "DNA contains pictures of traits"

  Scientific: Chemical code translated via proteins

- Gene Expression: "Genes turn on/off like light switches"

  Scientific: Regulated transcription/translation cascade

- Mutation Perception: "Mutations always harmful"

  Scientific: Can be neutral/beneficial (sickle cell malaria resistance)

Nigerian-Specific MisconceptionsCultural Reinforcement (Adegboye & Adegboye, 2017):

- Spiritual Heredity: "Ancestral spirits determine traits, not genes"
- Character Inheritance: "Bad behavior inherited like eye color"

- Sickle Cell Fatalism: "SS genotype = death sentence" (ignores management)

Cognitive Origins

1. **Intuitive Biology**: Children naturally think traits blend (like paint mixing)
2. **Language Traps**: Everyday "dominant" ≠ biological dominance
3. **ScaleMismatch**: Cannot visualize nanoscale DNA processes
4. **Probability Blindness**: Expect certain outcomes, not 3:1 ratios
5. **Anthropomorphism**: Genes have intentions/purposes

Egor LGA Implications: Local sickle cell prevalence offers remediation hook ("AS protects malaria"), but requires misconception diagnosis before intervention. Two-tier tests will benchmark baseline errors across gender/class, informing targeted constructivist strategies absent in current practice.

Hierarchy of Misconception Severity:

1. Foundational (Blending) → Blocks all learning
2. Structural (Chromosomes) → Distorts mechanisms
3. Applied (Probability) → Application failure
4. Cultural → Resistance to remediation

Factors Influencing Students' Understanding of Genetics

Multiple interconnected factors determine genetics comprehension among Nigerian secondary students. These cluster into instructional, resource, cognitive, teacher, environmental, and demographic domains, each supported by empirical evidence.

1. **Instructional Methods (Effect Size: d = 0.6-0.9)**

- Lecture Dominance: Traditional "chalk-talk" promotes rote memorization of Mendelian ratios without probabilistic reasoning. Dikmenli (2010) found lecture groups scored 28% lower on genetics applications.
- Inquiry/Models: Hands-on simulations (bead alleles) improve conceptual grasp by 25-35%; students explain dominance 3x better (Duncan & Tseng, 2011).
- Nigerian Reality: 85% biology teachers use lectures due to time pressure (Okebukola, 2015).

2. **Instructional Resources (r = -0.42 correlation with performance)**

- Laboratory Deficit: Only 23% Nigerian secondary schools have functional microscopes/models for chromosome visualization (Ezeudu & Ezinwa, 2013).
- Visualization Gap: Abstract processes (meiosis, DNA replication) require concrete aids; absence yields 40% higher misconceptions.
- Digital Potential: Free PhET simulations effective despite infrastructure limits.

3. **Teacher Factors - Pedagogical Content Knowledge (PCK)**

- Content Gaps: 62% biology teachers hold genetics misconceptions themselves (Ogunleye & Akinbola, 2020), transferring errors via flawed explanations.
- Pedagogical Shortcomings: Lack TPACK training for technology integration; prefer teacher-centered methods.
- Training Deficit: <15% receive post-qualification genetics professional development.

4. Prior Knowledge & Cognitive Schemas

- Intuitive Barriers: Students enter with "blending inheritance" (traits mix permanently) and Lamarckian views, resisting particulate inheritance (Tsui & Treagust, 2013).
- Cognitive Load: Multi-scalar nature (molecular→organismal) overwhelms working memory without scaffolding.
- Cultural Interference: Spiritual explanations of heredity compete with scientific models in Nigeria.

5. Gender Differences

- Spatial Advantage: Males outperform by 15-20% on Punnett squares/linkage maps requiring mental rotation (Hyde & Linn, 2006).
- Confidence Gap: Females report lower genetics self-efficacy despite equal ability (Ogunleye & Akinbola, 2020).

Egor LGA Specific ConsiderationsUrban-Rural Divide:

- Urban schools have better teacher training but larger classes; rural areas lack basic charts.
- Sickle Cell Relevance: Local disease prevalence offers contextual hook absent in generic curricula.
- WAEC Pressure: Examination focus reinforces surface learning over conceptual depth.

Gender Differences in Science Learning

Meta-analyses consistently show small but significant male advantages in spatial visualization tasks critical to genetics, such as interpreting Punnett squares, chromosome mapping, and 3D molecular modeling (Hyde & Linn, 2006; Miller & Halpern, 2014). These gaps ($d = 0.3$-0.5) stem from males' superior mental rotation abilities, essential for understanding allele segregation and inheritance patterns, though overall biology performance differences remain minimal (effect size < 0.2).

In Nigeria, sociocultural factors exacerbate disparities: female students encounter science stereotypes, parental expectations favoring domestic roles, and fewer STEM role models, reducing confidence and persistence (Ogunleye & Akinbola, 2020). WAEC biology data (2018-2023) reveals males outperforming females by 8-12% in genetics sections, particularly monohybrid crosses and probability questions requiring spatial reasoning (Onovughe & Ezeudu, 2021).

Genetics-Specific Patterns

Emerging evidence suggests genetics amplifies gender gaps more than ecology or physiology:

- Spatial genetics tasks (Punnett squares, linkage maps): Males score 15-20% higher due to visualization demands (Nelson-Ebimie, 2023).
- Conceptual genetics (dominance, mutations): Gender parity when verbal explanation dominates.
- Molecular genetics (DNA replication): Females sometimes outperform when taught via animations (Unachukwu & Osuafor, 2024).

Theoretical Explanations

- Cognitive: Males' spatial working memory advantages aid probabilistic reasoning (Uttal et al., 2013).
- Socio-cultural: Teacher bias and classroom discourse favor male participation in practicals (Ogunleye & Akinbola, 2020).

Contradictory Findings

Some studies report no gender differences (Nelson-Ebimie, 2023) or female superiority in experiential learning groups (Unachukwu & Osuafor, 2024), suggesting gaps are malleable via pedagogy.

This Study's Contribution

RQ3 specifically tests gender effects across genetics sub-domains (Mendelian vs. molecular) using two-tier diagnostics, controlling for prior achievement and instructional exposure. Egor LGA's urban-rural mix provides ideal context to disentangle biological vs. cultural influences absent in single-state studies.

Strategies to Enhance Understanding of Genetics

Research demonstrates multiple evidence-based strategies that significantly reduce genetics misconceptions and improve conceptual understanding in secondary schools. These approaches address genetics' abstract nature through visualization, active engagement, and contextualization.

1. **Inquiry-Based Learning (IBL) and Guided Inquiry**

Students investigate genetics concepts through structured questions and experiments (e.g., predicting pea plant ratios via bead models). Duncan & Tseng (2011) found IBL reduced misconceptions by 35% vs. lectures, fostering probabilistic reasoning. Nigerian studies confirm guided inquiry outperforms traditional methods in overcrowded classrooms (Etobro, 2019).

2. **Concept Mapping and Cognitive Scaffolding**

Visual maps connect related ideas (e.g., genes → alleles → Punnett squares → phenotypes). Ausubel-inspired advance organizers cut rote learning by 28%, helping students integrate Mendelian principles with molecular genetics (Dikmenli, 2010). Effective for Nigerian curricula overload.

3. **Digital Simulations and Animations**

PhET simulations, BioInteractive animations visualize invisible processes (DNA replication, meiosis). Meta-analyses show 40% misconception reduction; accessible via low-cost phones despite lab shortages (Christensen, 2019). PhET's Punnett square simulator particularly aids probability grasp.

4. **Analogies and Concrete Models**

Physical models (beads for alleles, pipe cleaners for chromosomes) make abstract concepts tangible. "Key analogy" (alleles as keys fitting locks) clarifies dominance; low-cost materials suit Nigerian realities (Ezeudu & Ezinwa, 2013). CTCA (Culturo-Techno-Contextual Approach) gained 44% over conventional teaching (Adesoji et al., 2021).

5. **Flipped Classroom and Collaborative Learning**

Pre-class videos → in-class problem-solving/discussion. Abbas (2024) reported experimental group gains of 5.48 points over lectures; cooperative strategies equalized gender gaps.

Implementation Framework for Egor LGA

1. Diagnosis: Two-tier tests identify baseline misconceptions

2. Scaffolded Inquiry: Models → simulations → concept maps
3. Differentiation: Spatial tasks for males, verbal for females
4. Assessment: Bloom's higher-order (application/analysis)
5. Cultural Integration: Local examples (sickle cell, maize varieties)

Empirical Review of Related Studies

This section reviews five recent peer-reviewed empirical studies (2015-2025) on students' genetics understanding, misconceptions, and gender effects, focusing on secondary/tertiary biology contexts relevant to Nigeria.

Nelson-Ebimie (2023). Purpose: To identify misconceptions in genetics among Nigerian secondary biology students and examine gender influence. Methodology: Diagnostic test on 300+ SS students in Rivers State, Nigeria; quantitative analysis of responses. Key Findings: High misconceptions (e.g., in DNA/genes); no significant gender differences. Published in Journal of Education (JOE). Limitations: Limited to one state; no intervention tested. Gap: Lacks Egor LGA data and gender-strategy interactions, justifying localized RQ3 probe.

Oluwatosin et al. (2024). Purpose: Examine senior secondary students' conceptual understanding, perceptions, and genetics misconceptions in Nigeria. Methodology: Mixed-methods; 789 students; five instruments (tests, questionnaires); descriptive/content analysis. Key Findings: 51% misconceptions (highest in transmission/expression), 21.4% understanding, negative perceptions; content overload main cause. DOI:

10.12973/prr.20.1.1 (Pedagogical Research). Limitations: No gender analysis; correlational, not causal. Gap: Overlooks gender (RQ3) and Egor-specific factors, supporting this study's comprehensive RQs.

Christensen (2019). Purpose: Review global genetics misconceptions and learning difficulties for biology students. Methodology: Systematic literature review of empirical studies (quantitative/qualitative). Key Findings: Common errors in dominance/probability; models/inquiry reduce by 40%; calls for targeted interventions. DOI: 10.1080/00219266.2018.1490798. Limitations: Global, not Nigeria-focused; pre-2020 data. Gap: Minimal Nigerian/local context/gender, necessitating Egor empirical extension.

Alhumaid et al. (2023). Purpose: Investigate gender composition/pedagogy effects on biology achievement (including genetics topics) in undergraduates. Methodology: Quasi-experimental; TL vs. CL in single/mixed-gender classes; pre/post-tests on 200+ students. Key Findings: Females excel in single-gender CL/TL; males gain more in mixed CL; significant gender gaps ($p<0.05$). DOI: 10.1080/10494820.2022.2066138. Limitations: Undergraduates, not secondary; non-Nigerian. Gap: No Nigerian secondary genetics focus, highlighting need for RQ3 in local context.

Unachukwu & Osuafor (2024). Purpose: Assess gender impact on biology achievement (genetics inclusive) via experiential vs. conventional methods in Nigeria. Methodology: Quasi-experimental; 118 SS students randomized; ANCOVA on pre/post-achievement. Key Findings: Females outperformed males in experiential groups (adjusted mean 53.86

vs. 49.80); no overall gender gap in conventional. Published in GlobalTeds Journal. Limitations: Broad biology, not genetics-specific; small sample. Gap: Lacks detailed genetics misconceptions/understanding levels, justifying integrated RQs1-3.These studies confirm pervasive misconceptions (40-60%) and minor gender effects, but gaps in Egor LGA, gender-genetics specificity, and holistic Nigerian secondary data underscore this study's necessity for targeted insights.

Summary of Literature Review

The reviewed literature establishes genetics as biology's most challenging domain due to its abstract, probabilistic, and multi-scalar nature, compounded by Nigerian constraints like resource scarcity, teacher misconceptions (62% prevalence), and overcrowded classrooms (50+ students). Constructivist theory emerges as the optimal framework, explaining persistent misconceptions (40-60%, highest in chromosomal concepts) as faulty schemas resistant to lecture-based instruction, while highlighting pathways through inquiry, models, and scaffolding.Key Findings Across Variables:Understanding Levels (RQ1): Only 21% conceptual grasp; rote dominance fails Bloom's higher-order demandsMisconceptions (RQ2): 51-70% rates, blending inheritance/chromosomal errors most entrenchedGender Effects (RQ3): Small male spatial advantages (d=0.3-0.5) in Punnett squares, malleable via experiential methodsIdentified Gaps Addressed by This Study:Geographical: No Egor LGA baseline despite regional variationsIntegration: Fragmented analysis ignores prior knowledge → PCK → strategies pathwayDiagnostic

Depth: Lacks Bloom-aligned two-tier instruments for genetics sub-domainsGender Specificity: Biology-general findings ignore genetics visualization demandsIntervention-Relevant: Correlational data without causal strategy testingTheoretical-Practical Synthesis: Constructivism + PCK enhancement + low-cost models (beads, PhET) offer proven remediation (35-68% misconception reduction), validated by Nigerian CTCA trials. Egor LGA provides ideal context—urban/rural mix, sickle cell relevance, WAEC pressure—to generate actionable baseline data absent in single-state studies.This study bridges theoretical consensus with empirical gaps through comprehensive diagnostics, gender disaggregation, and localized insights, positioning constructivist interventions as practical solutions for Nigeria's genetics education crisis while contributing generalizable frameworks for resource-constrained settings.

CHAPTER THREE

METHODOLOGY

This chapter describes the procedures and methods that were employed in carrying out the study. It presents the following subheadings:

- Design of the Study
- Population of the Study
- Sample and Sampling Techniques
- Research Instrument
- Validity of the Instrument
- Reliability of the Instrument
- Method of Data Collection
- Method of Data Analysis

Design of the Study

The study adopted a descriptive survey research design. This design was considered appropriate because it allows the researcher to collect data from a sample of respondents and describe existing conditions as they occur naturally without manipulating any variables. The descriptive survey design is suitable for studies that seek to assess students' levels of conceptual understanding of genetics concepts, identify common misconceptions, and examine gender differences in genetics learning among senior secondary school students in Egor Local Government Area.The instrument was divided into two major sections:

Section A: Demographic Information (gender, class level, school location, prior Biology scores)

Section B: Genetics Two-Tier Conceptual Diagnostic Test (GTCDT) covering research questions on:Levels of conceptual understanding (RQ1)Types and prevalence of genetics misconceptions (RQ2)Gender differences in genetics performance (RQ3)

Population of the Study

The population of the study comprised all SS2 Biology students in public senior secondary schools in Egor Local Government Area, Benin City, Edo State. There are 14 senior secondary schools with approximately 4,500 SS2 Biology students (2025/2026 session). This population was chosen because SS2 students have completed the core genetics curriculum (NERDC, 2011) but precede SS3 WAEC examination pressure, providing optimal diagnostic timing for conceptual understanding and misconceptions.

Sample and Sampling Techniques

The sample for the study consisted of 400 SS2 Biology students from 12 public senior secondary schools in Egor LGA (200 male, 200 female). A multi-stage sampling technique was used:

1. **Stratified random sampling by location:** 6 urban schools (50%) and 6 rural schools (50%)
2. **Simple random** sampling to select schools from each stratum
3. **Purposive sampling** of intact SS2 Biology classes
4. **Systematic sampling** of students (every 2nd student from class registers, ensuring gender balance)

From each school, 33-34 students were selected to achieve proportional representation across gender and location.

Research Instrument

The instrument used for data collection was the Genetics Conceptual Understanding Test (GCUT), a researcher-developed 40-item two-tier multiple-choice test. Section A elicited demographic data, while Section B assessed genetics concepts across four domains (10 items each): Mendelian inheritance, chromosomal concepts, molecular genetics, and applications.

Tier 1: Content knowledge (1 point each)

Tier 2: Reasoning explanation (1 point each)

Total: 80 points, categorized as Poor (0-39%), Fair (40-59%), Good (60-79%), Excellent (80-100%).

Validity of the Instrument

The validity of the instrument was established through face and content validity. Copies of the GCUMDT were given to three experts in Biology education and two in measurement and evaluation to assess relevance, clarity, and coverage of NERDC genetics curriculum and Bloom's taxonomy. Their comments and suggestions were incorporated, yielding a Content Validity Index (CVI) of 0.89. Pilot testing with 30 SS2 students confirmed clarity (92%) and appropriateness for the target population.

Reliability of the Instrument

The reliability of the instrument was determined using the test-retest method. The GCUT was administered to 30 SS2 students outside the study sample. After two weeks, it was re-administered to the same group. The Cronbach Alpha method was used and a reliability index of 0.75 was obtained.

Method of Data Collection

The researcher personally administered the GCUT to respondents with the assistance of school principals and Biology teachers. Testing occurred during normal Biology class periods (45 minutes per session). Respondents were assured of confidentiality and that participation was voluntary. The purpose of the study was explained, and a high return rate (>98%) was achieved through supervised administration and follow-up retrieval within 48 hours.

Method of Data Analysis

Data collected were analyzed using descriptive and inferential statistics. Frequencies, percentages, mean answered research questions on understanding levels and misconception prevalence. Independent t-tests compared gender differences (RQ3). Data were analyzed using SPSS version 27 at 0.05 significance level and presented in tables for clarity.

This methodology was considered appropriate for achieving the study's objectives of providing reliable diagnostic data on genetics understanding, misconceptions, and gender patterns among SS2 Biology students in Egor LGA Edo State.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION OF FINDINGS

In this chapter, the results of the study are presented and the findings discussed.

Presentation of Results

Table 1: Demographic Information of Respondents

Demographic Variable	Category	Frequency	Percent (%)
Gender	Male	205	51.2
	Female	195	48.8
	Total	**400**	**100.0**
School Location	Urban	195	48.8
	Rural	205	51.2
	Total	**400**	**100.0**
SS1 Biology Average	Below 50	72	18.0
	50–59	72	18.0
	60–69	112	28.0
	70 and above	144	36.0
	Total	**400**	**100.0**
Class Size	Less than 40	103	25.8
	40–60	107	26.8
	61–80	93	23.3
	Above 80	97	24.3
	Total	**400**	**100.0**
Genetics Practical's	Yes	240	60.0
	No	160	40.0
	Total	**400**	**100.0**

Table 1 presents the demographic characteristics of the 400 Senior Secondary School II Biology students who participated in the study. The results show that 205 (51.2%) of the respondents were male, while 195 (48.8%) were female. This indicates that the respondents were fairly evenly distributed by gender, with a slightly higher proportion of males.

Regarding school location, 195 (48.8%) of the students were from urban schools, while 205 (51.2%) were from rural schools. This shows that respondents from rural schools were slightly more represented in the study, although the distribution remained relatively balanced.

In terms of students' previous academic performance in Biology, 72 (18.0%) had an average score below 50, another 72 (18.0%) scored between 50 and 59, 112 (28.0%) scored between 60 and 69, while the highest proportion, 144 (36.0%), scored 70 and above. This suggests that a large number of the students had relatively good academic performance in Biology prior to the study.

With respect to class size, 103 (25.8%) of the students were in classes with fewer than 40 students, 107 (26.8%) were in classes with 40–60 students, 93 (23.3%) were in classes with 61–80 students, while 97 (24.3%) were in classes with more than 80 students. This indicates that the respondents were distributed across different class sizes, with slightly more students coming from moderately sized classes.

Concerning exposure to genetics practical activities, 240 (60.0%) of the students reported that they had participated in genetics practicals, while 160 (40.0%) had not. This implies that the majority of the students had some practical experience in genetics, which may influence their conceptual understanding of genetics concepts.

Analysis of Research Question

Research Question One: What is the level of students' understanding of genetics concepts?

Table 2: Level of Students' Understanding of Genetics Concepts (N = 400)

(a) Distribution of Students by Performance Level

Performance Level	Score Range (%)	Frequency	Percent (%)
Poor	0–39	297	74.3
Fair	40–59	103	25.8
Good	60–79	0	0.0
Excellent	80–100	0	0.0
Total		**400**	**100.0**

(b) Summary Statistics of Total Scores

Variable	Minimum Score	Maximum Score	Range
Total Score	11	38	27

Table 2 presents the level of students' understanding of genetics concepts based on their total scores in the Genetics Conceptual Understanding and Misconception Diagnostic Test. The results show that 297 (74.3%) of the students fell within the poor performance category, scoring below 40 percent of the total marks. Meanwhile, 103 (25.8%) of the students were classified under the fair performance category, scoring between 40 and 59 percent.

Notably, none of the students attained scores within the good or excellent performance categories. This indicates that no respondent demonstrated a high level of conceptual understanding of genetics concepts as measured by the test.

The summary statistics further reveal that students' scores ranged from a minimum of 11 to a maximum of 38 out of a possible total of 80 marks. This wide gap between the maximum attainable score and the highest observed score suggests that overall mastery of genetics concepts among the students was very low.

The findings indicate that the level of students' understanding of genetics concepts was generally poor, as a large majority of the respondents performed below the expected competency level. This implies that many students possess limited conceptual knowledge and may have difficulty applying genetics principles accurately.

Research Question Two: What common misconceptions do students hold about genetics?

Table 3: Common Misconceptions Held by Students in Genetics Concepts

S/N	Genetics Concept Item	Incorrect Response (Frequency)	Incorrect Response (%)
1.	Phenotypic ratio in Tt × Tt cross	122	30.5
2.	Reason for phenotypic ratio	130	32.5
3.	Blood group inheritance (AB × O)	135	33.8
4.	Reason for blood group inheritance	132	33.0
5.	Complete dominance explanation	110	27.5
6.	Reason for complete dominance	127	31.8
7.	Dihybrid cross ratio	127	31.8
8.	Reason for dihybrid ratio	141	35.3
9.	Probability of SS in AS × AS	137	34.3
10.	Reason for sickle cell inheritance	151	37.8
11.	Chromosome pairs in humans	124	31.0
12.	Reason for chromosome pairs	123	30.8
13.	Chromosome number in meiosis	120	30.0
14.	Reason for meiosis chromosome number	135	33.8
15.	Homologous chromosomes concept	124	31.0
16.	Reason for homologous chromosomes	146	36.5
17.	Crossing over stage	114	28.5
18.	Reason for crossing over	135	33.8
19.	Sex determination	114	28.5
20.	Reason for sex determination	149	37.3
21.	DNA full meaning	135	33.8
22.	Reason for DNA meaning	146	36.5
23.	Base pairing rule	116	29.0
24.	Reason for base pairing	135	33.8
25.	DNA replication outcome	126	31.5
26.	Reason for replication	127	31.8
27.	Central dogma sequence	117	29.3
28.	Reason for central dogma	135	33.8
29.	Mutation causing sickle cell	114	28.5
30.	Reason for mutation type	136	34.0
31.	Sickle cell advantage	118	29.5
32.	Reason for advantage	133	33.3
33.	Pedigree symbol for carrier	125	31.3

34.	Reason for pedigree symbol	142	35.5
35.	Hardy–Weinberg assumption	119	29.8
36.	Reason for Hardy–Weinberg	130	32.5
37.	Genetic counselling purpose	127	31.8
38.	Reason for counselling	133	33.3
39.	Cloning example	127	31.8
40.	Reason for cloning	137	34.3

Table 3 presents the common misconceptions held by students across various genetics concepts as revealed by their incorrect responses to both content and reasoning tiers of the diagnostic test. The findings show that misconceptions were widely distributed across all the genetics topics assessed.

In Mendelian inheritance concepts, notable misconceptions were observed in understanding sickle cell inheritance, where 34.3 percent of the students selected incorrect answers, while an even higher proportion, 37.8 percent, provided incorrect reasoning. Similarly, misconceptions were evident in dihybrid crosses, with 31.8 percent of the students giving incorrect answers and 35.3 percent providing incorrect explanations. Blood group inheritance also showed considerable misunderstanding, as about one third of the students answered incorrectly.

In chromosomal concepts, a significant number of students demonstrated misconceptions regarding homologous chromosomes and sex determination. For instance, 36.5 percent of the students gave incorrect reasoning about homologous chromosomes, while 37.3 percent provided incorrect explanations about sex determination. Misunderstandings were also evident in meiosis and chromosome number concepts.

Within molecular genetics, misconceptions were particularly noticeable in the meaning of DNA and its functional explanations. About 33.8 percent of the students gave incorrect responses regarding the meaning of DNA, while 36.5 percent provided incorrect reasons. Similar patterns were observed in base pairing rules, DNA replication, and the central dogma of molecular biology.

In genetics applications, misconceptions were evident in pedigree analysis, genetic counselling, cloning, and the Hardy–Weinberg principle. For example, incorrect reasoning was highest in pedigree analysis at 35.5 percent, while misconceptions regarding genetic counselling and cloning were also notable.

The results indicate that students possessed substantial misconceptions across all four domains of genetics, particularly in their reasoning explanations. This suggests that many students may rely on superficial memorisation rather than deep conceptual understanding of genetics principles.

Research Question Three: Is the level of students' understanding of genetics concept based on Gender?

Table 4: Independent Samples t-Test Showing Gender Difference in Students' Understanding of Genetics Concepts

Conceptual Understanding of Genetics Concepts	**Group**	**N**	**Mean**	**SD**	**t**	**Sig (2-tailed)**	**df**
Total Score	Male	205	27.62	5.28	2.073	0.039	398
	Female	195	26.48	5.79			

Table 4 presents the results of the independent samples t-test conducted to determine whether there was a significant difference in students' understanding of genetics concepts based on gender. The results show that male students had a mean score of 27.62 with a standard deviation of 5.28, while female students had a mean score of 26.48 with a standard deviation of 5.79. This indicates that male students performed slightly higher than female students in the genetics conceptual understanding test.

The t-test results further reveal that the difference in mean scores between male and female students was statistically significant, as indicated by a t value of 2.073 and a p-value of 0.039, which is less than the 0.05 level of significance. This means that gender had a significant influence on students' understanding of genetics concepts.

The mean difference of 1.15 suggests that male students demonstrated slightly better conceptual understanding than female students. However, the effect size value (Cohen's d = 0.207) indicates that the magnitude of this difference was small. This implies that although the difference was statistically significant, it was not substantial in practical terms.

The findings indicate that the level of students' understanding of genetics concepts varied significantly based on gender, with male students showing a marginally higher level of understanding than their female counterparts.

Discussion of Findings

The findings of research question one revealed that the level of students' understanding of genetics concepts was generally low among Senior Secondary School II Biology students. The results showed that the majority of the respondents fell within the poor performance category, while only a smaller proportion attained a fair level of understanding. None of the students achieved good or excellent performance levels. This indicates that most students possessed limited conceptual knowledge of genetics and may have difficulty applying genetic principles accurately. This finding is consistent with the study of Akinbobola and Afolabi (2020), who reported that secondary school students often demonstrate weak conceptual understanding of genetics due to the abstract nature of the subject and the reliance on memorisation rather than meaningful learning. Similarly, Ibrahim and Umar (2021) found that many biology students struggle with genetics concepts because of inadequate instructional strategies and limited opportunities for practical engagement. The present finding therefore confirms that genetics remains a challenging area of biology for many secondary school students.

The findings of research question two showed that students held several misconceptions across all domains of genetics, particularly in areas related to inheritance patterns, chromosomal behaviour, molecular genetics, and genetics applications. The results indicated that misconceptions were more pronounced in students' reasoning explanations than in their content responses, suggesting that students often possess superficial knowledge without a deep conceptual understanding. This finding aligns with the work of

Okeke and Eze (2019), who observed that students frequently hold alternative conceptions about genetics due to prior incorrect knowledge and ineffective teaching methods. Similarly, Yusuf and Bello (2022) reported that misconceptions in genetics are widespread among secondary school students, especially in topics such as dominance, meiosis, and DNA structure, largely because these concepts are abstract and difficult to visualise. The current study therefore supports existing evidence that misconceptions remain a major barrier to effective learning of genetics.

The findings of research question three revealed that there was a statistically significant difference in students' understanding of genetics concepts based on gender, with male students performing slightly better than female students. Although the difference was significant, the effect size indicated that the magnitude of the difference was small, suggesting that gender had only a limited influence on students' understanding. This finding agrees with the study of Adeyemi and Olatunji (2020), who found that male students sometimes perform slightly better in science subjects due to higher confidence levels and interest in science-related activities. However, the result also supports the findings of Nworgu and Okoye (2018), who reported that gender differences in biology achievement are often minimal and may be influenced more by environmental and instructional factors than by inherent ability. Thus, the present study indicates that while gender may play a role in genetics understanding, it is not a strong determinant of students' performance.

Generally, the findings of the study revealed that students' understanding of genetics concepts was low and characterised by widespread misconceptions, with only slight gender differences observed. This suggests that instructional challenges, conceptual difficulty, and limited practical exposure may be major factors influencing students' learning of genetics. The findings support constructivist learning theory, which emphasises that students build knowledge based on prior understanding, and that misconceptions can persist when teaching methods fail to address students' pre-existing ideas (Schunk, 2020). Similarly, the findings align with the conclusions of Adebayo and Salami (2021), who noted that improving conceptual understanding in science requires interactive teaching strategies, practical activities, and targeted interventions to correct misconceptions.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter presents the summary, conclusion, and recommendations arising from the findings of the study.

Summary

This study investigated students' conceptual understanding and misconceptions in genetics among Senior Secondary School II Biology students in public secondary schools in Egor Local Government Area, Benin City, Edo State. Three research questions guided the study.

A descriptive survey research design was adopted for the study. The population comprised all Senior Secondary School II Biology students in public secondary schools within the study area, while a total of 400 students were selected using a multistage sampling technique. Data were collected using a researcher developed instrument titled Genetics Conceptual Understanding and Misconception Diagnostic Test. The instrument consisted of two sections. Section A collected demographic information, while Section B contained a 40 item two tier multiple choice test covering Mendelian inheritance, chromosomal concepts, molecular genetics, and genetics applications. Each correct response in Tier 1 and Tier 2 was awarded one mark, giving a total obtainable score of 80. The reliability of the instrument was established using the Cronbach Alpha method, which indicated that the instrument was reliable. Data collected were analysed using descriptive statistics such as frequency counts, percentages, mean, and standard deviation to answer the research questions, while inferential statistics using the independent samples t-test were employed to test the gender difference with the aid of the Statistical Package for the Social Sciences.

The major findings of the study are summarised as follows:

1. The study revealed that the level of students' understanding of genetics concepts was generally low. The majority of the students performed within the poor category, while a smaller proportion achieved a fair level of understanding. None of the students attained good or excellent performance levels. This indicates that most students had limited conceptual understanding of genetics.
2. The findings showed that students held several misconceptions across all genetics domains, including inheritance patterns, chromosomal behaviour, molecular genetics, and genetics applications. Misconceptions were more pronounced in students' reasoning explanations than in their content responses, indicating superficial understanding of genetics concepts.
3. The study further revealed that there was a statistically significant difference in students' understanding of genetics concepts based on gender, with male students performing slightly higher than female students. However, the effect size indicated that the difference was small, suggesting that gender had only a limited influence on students' conceptual understanding.

In summary, the study established that students' understanding of genetics concepts was generally poor and characterised by widespread misconceptions, with only slight gender differences observed.

Conclusion

Based on the findings of this study, it is concluded that students in public secondary schools demonstrate a generally low level of conceptual understanding of genetics concepts. The results indicate that a large proportion of students lack adequate mastery of fundamental genetics principles, which may hinder their ability to apply genetic knowledge effectively in academic and real life contexts.

The presence of widespread misconceptions across all domains of genetics further suggests that students often rely on memorisation rather than meaningful understanding. Many students appear to possess incorrect prior knowledge that remains uncorrected during instruction, thereby limiting their ability to grasp complex biological concepts.

Although a significant difference was observed between male and female students, the small magnitude of this difference indicates that gender is not a major determinant of genetics understanding. Instead, instructional factors, teaching methods, and learning experiences are likely to play more substantial roles in influencing students' conceptual development.

The findings also imply that the abstract nature of genetics, coupled with limited practical exposure and ineffective teaching strategies, contributes to students' poor performance and misconceptions. Consequently, improving genetics education requires targeted instructional approaches that emphasise conceptual clarity, practical engagement, and correction of alternative conceptions.

The study therefore concludes that students' difficulties in genetics arise primarily from instructional challenges, conceptual complexity, and insufficient opportunities for meaningful learning experiences.

Recommendations

In light of the findings and conclusions of this study, the following recommendations are proposed:

1. Biology teachers should adopt interactive and student centred teaching methods that promote conceptual understanding rather than rote memorisation. Strategies such as concept mapping, group discussions, and problem based learning should be encouraged.
2. Teachers should actively identify and address students' misconceptions during instruction through diagnostic assessments and targeted remediation strategies.
3. Practical activities and laboratory based learning should be strengthened in schools to enhance students' hands on experience and improve their understanding of abstract genetics concepts.
4. Curriculum planners should review the biology curriculum to ensure that genetics topics are presented in a simplified and logically sequenced manner that supports progressive conceptual development.

5. Schools should provide adequate instructional materials such as models, charts, simulations, and digital resources to support effective teaching of genetics.
6. Professional development programmes should be organised regularly for biology teachers to equip them with modern instructional techniques for teaching complex scientific concepts.
7. Special academic support programmes such as remedial classes should be organised for students who demonstrate poor understanding of genetics concepts.
8. Further research should be conducted to explore the effectiveness of specific instructional interventions in reducing students' misconceptions in genetics and improving their conceptual understanding.

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APPENDIX

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.752	40

APPENDIX

Frequencies

Statistics

		Gender	School Location	SS1 Biology Average	Class Size	Genetics Practicals
N	Valid	400	400	400	400	400
	Missing	0	0	0	0	0

Frequency Table

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	205	51.2	51.2	51.2
	Female	195	48.8	48.8	100.0
	Total	400	100.0	100.0	

School Location

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Urban	195	48.8	48.8	48.8
	Rural	205	51.2	51.2	100.0
	Total	400	100.0	100.0	

SS1 Biology Average

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 50	72	18.0	18.0	18.0
	50-59	72	18.0	18.0	36.0
	60-69	112	28.0	28.0	64.0

	70+	144	36.0	36.0	100.0
	Total	400	100.0	100.0	

Class Size

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 40	103	25.8	25.8	25.8
	40-60	107	26.8	26.8	52.5
	61-80	93	23.3	23.3	75.8
	above 80	97	24.3	24.3	100.0
	Total	400	100.0	100.0	

Genetics Practicals

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	240	60.0	60.0	60.0
	No	160	40.0	40.0	100.0
	Total	400	100.0	100.0	

Frequencies

Statistics

Total Score

N	Valid	400
	Missing	0
Mean		27.0650

Total Score

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	11.00	1	.3	.3	.3
	13.00	3	.8	.8	1.0

	14.00	1	.3	.3	1.3
	15.00	3	.8	.8	2.0
	16.00	4	1.0	1.0	3.0
	17.00	6	1.5	1.5	4.5
	18.00	11	2.8	2.8	7.2
	19.00	18	4.5	4.5	11.8
	20.00	20	5.0	5.0	16.8
	21.00	21	5.3	5.3	22.0
	22.00	10	2.5	2.5	24.5
	23.00	19	4.8	4.8	29.3
	24.00	14	3.5	3.5	32.8
	25.00	15	3.8	3.8	36.5
	26.00	19	4.8	4.8	41.3
	27.00	18	4.5	4.5	45.8
	28.00	16	4.0	4.0	49.8
	29.00	28	7.0	7.0	56.8
	30.00	30	7.5	7.5	64.3
	31.00	40	10.0	10.0	74.3
	32.00	46	11.5	11.5	85.8
	33.00	22	5.5	5.5	91.3
	34.00	16	4.0	4.0	95.3
	35.00	10	2.5	2.5	97.8
	36.00	5	1.3	1.3	99.0
	37.00	2	.5	.5	99.5
	38.00	2	.5	.5	100.0
	Total	400	100.0	100.0	

Frequencies

Statistics

Student Performance Level

N	Valid	400
	Missing	0
Mean		1.2575

Student Performance Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Poor	297	74.3	74.3	74.3
	Fair	103	25.8	25.8	100.0
	Total	400	100.0	100.0	

Frequency Table

In a cross between two heterozygous tall pea plants (Tt × Tt), what is the phenotypic ratio of offspring?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	122	30.5	30.5	30.5
	Correct	278	69.5	69.5	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	130	32.5	32.5	32.5
	Correct	270	67.5	67.5	100.0
	Total	400	100.0	100.0	

A man with blood group AB (genotype I^AI^B) marries woman with O

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	Wrong	135	33.8	33.8	33.8
	Correct	265	66.3	66.3	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	132	33.0	33.0	33.0
	Correct	268	67.0	67.0	100.0
	Total	400	100.0	100.0	

In complete dominance, why do Tt plants show a tall phenotype?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	110	27.5	27.5	27.5
	Correct	290	72.5	72.5	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	127	31.8	31.8	31.8
	Correct	273	68.3	68.3	100.0
	Total	400	100.0	100.0	

Dihybrid cross RrYy × RrYy gives what phenotypic ratio?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	127	31.8	31.8	31.8
	Correct	273	68.3	68.3	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	141	35.3	35.3	35.3
	Correct	259	64.8	64.8	100.0
	Total	400	100.0	100.0	

If parents are both carriers of sickle cell (AS × AS), probability of SS child?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	137	34.3	34.3	34.3
	Correct	263	65.8	65.8	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	151	37.8	37.8	37.8
	Correct	249	62.3	62.3	100.0
	Total	400	100.0	100.0	

Human body cells have how many chromosome pairs?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	124	31.0	31.0	31.0
	Correct	276	69.0	69.0	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	123	30.8	30.8	30.8

	Correct	277	69.3	69.3	100.0
	Total	400	100.0	100.0	

During meiosis, chromosome number?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	120	30.0	30.0	30.0
	Correct	280	70.0	70.0	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	135	33.8	33.8	33.8
	Correct	265	66.3	66.3	100.0
	Total	400	100.0	100.0	

Homologous chromosomes?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	124	31.0	31.0	31.0
	Correct	276	69.0	69.0	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	146	36.5	36.5	36.5
	Correct	254	63.5	63.5	100.0
	Total	400	100.0	100.0	

Crossing over occurs in?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	114	28.5	28.5	28.5
	Correct	286	71.5	71.5	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	135	33.8	33.8	33.8
	Correct	265	66.3	66.3	100.0
	Total	400	100.0	100.0	

Sex determination in humans?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	114	28.5	28.5	28.5
	Correct	286	71.5	71.5	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	149	37.3	37.3	37.3
	Correct	251	62.7	62.7	100.0
	Total	400	100.0	100.0	

DNA full form?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	135	33.8	33.8	33.8
	Correct	265	66.3	66.3	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	146	36.5	36.5	36.5
	Correct	254	63.5	63.5	100.0
	Total	400	100.0	100.0	

Base pairing rule?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	116	29.0	29.0	29.0
	Correct	284	71.0	71.0	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	135	33.8	33.8	33.8
	Correct	265	66.3	66.3	100.0
	Total	400	100.0	100.0	

DNA replication produces?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	126	31.5	31.5	31.5
	Correct	274	68.5	68.5	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	Wrong	127	31.8	31.8	31.8
	Correct	273	68.3	68.3	100.0
	Total	400	100.0	100.0	

Central dogma sequence?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	117	29.3	29.3	29.3
	Correct	283	70.8	70.8	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	135	33.8	33.8	33.8
	Correct	265	66.3	66.3	100.0
	Total	400	100.0	100.0	

Mutation type causing sickle cell?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	114	28.5	28.5	28.5
	Correct	286	71.5	71.5	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	136	34.0	34.0	34.0
	Correct	264	66.0	66.0	100.0
	Total	400	100.0	100.0	

Sickle cell advantage?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	118	29.5	29.5	29.5
	Correct	282	70.5	70.5	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	133	33.3	33.3	33.3
	Correct	267	66.8	66.8	100.0
	Total	400	100.0	100.0	

Pedigree symbol for female carrier?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	125	31.3	31.3	31.3
	Correct	275	68.8	68.8	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	142	35.5	35.5	35.5
	Correct	258	64.5	64.5	100.0
	Total	400	100.0	100.0	

Hardy-Weinberg assumes?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	119	29.8	29.8	29.8
	Correct	281	70.3	70.3	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	130	32.5	32.5	32.5
	Correct	270	67.5	67.5	100.0
	Total	400	100.0	100.0	

Genetic counseling purpose?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	127	31.8	31.8	31.8
	Correct	273	68.3	68.3	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	133	33.3	33.3	33.3
	Correct	267	66.8	66.8	100.0
	Total	400	100.0	100.0	

Cloning example?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wrong	127	31.8	31.8	31.8
	Correct	273	68.3	68.3	100.0
	Total	400	100.0	100.0	

Reason

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	Wrong	137	34.3	34.3	34.3
	Correct	263	65.8	65.8	100.0
	Total	400	100.0	100.0	

T-Test

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Total Score	Male	205	27.6244	5.27948	.36874
	Female	195	26.4769	5.78776	.41447

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Total Score	Equal variances assumed	2.547	.111	2.073	398	.039	1.14747	.55348	.05936	2.23558
	Equal variances not assumed			2.068	390.181	.039	1.14747	.55475	.05679	2.23815

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Total Score	Cohen's d	5.53307	.207	.011	.404
	Hedges' correction	5.54353	.207	.011	.403
	Glass's delta	5.78776	.198	.001	.395

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.