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Examination of Secondary School Students' Conceptual Understanding, Perceptions, and Misconceptions about Genetics Concepts

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ABSTRACT

Genetics concepts are taught in Nigerian secondary schools to equip students with the necessary knowledge, attitudes, and skills to engage with socioscientific issues and make informed decisions. However, previous research indicates poor student comprehension of these concepts despite multiple interventions. This study examined senior school students' understanding, perceptions, and misconceptions about genetics, as well as the causes of these misconceptions. Using a mixed-methods sequential explanatory design (QUAN+qual), data from 789 students were analyzed with descriptive statistics and content analysis. Findings revealed that only 21.4% of students understood genetics concepts, 27.6% did not, and 51.0% had misconceptions. Students generally had negative perceptions of genetics concepts. The primary cause of misconceptions was the genetic content itself, followed by instructional materials, teacher/school factors, and student-related factors. Many respondents noted that recommended biology textbooks were insufficiently detailed. To improve genetics education, teaching should be supported with relevant instructional materials and textbooks that are detailed and activity-oriented, evaluated by experts in the field.

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1. INTRODUCTION

Genetics, in this genomics era of molecular activities, is now seen as an essential concept that is fundamental to the teaching and learning of biology, as well as different research in biomedical sciences (Tsui & Treagust, 2007). This biology concept is also central for understanding some controversial issues related to genetics such as cloning, genetically modified organisms (GMOs), and selection of sex, among others, and it has been appearing in human lives more frequently than ever before in areas of our health and reproduction, while information about genetically modified organisms, fingerprinting, genetic diseases, cloning, gene therapy is widespread among us. This progress makes it an important concept that every citizen must understand to make informed choices in their lives and also shows why genetic education is more essential than before in the school biology curriculum (Vlckova *et al*., 2016). The Nigeria Federal Ministry of Education (FME) understood this need, and made genetics a well-established concept in biology curricula, even at the secondary school level. At this level of education, genetics is one of the several concepts that are thematically taught in biology. It deals with the study of genes, how genes are inherited and transferred, as well as the variation, functions, and behaviors of genes. The sub-topics found under genetics in Nigeria's secondary school biology curriculum include principles of heredity, the transmission of inheritable characters from parents to their offspring via genes, and variation; differences that occur within the individuals of a species, sex determination, probability, application of probability, sex-linkage, and use of heredity principle. Furthermore, it is one of the few concepts in biology that help students acquire abilities such as reasoning, problem-solving, and reflective thinking. Genetics instruction at secondary school also provides a considerable opportunity for students to engage and discuss current and related moral as well as ethical issues (Ashelford, 2008) to be informed, and make a reasonable decision.

However, despite the importance of genetics, the Chief Examiner's Report for West Africa Examination Council Nigeria's biology examination indicated that this aspect of biology was unpopular among the secondary school students who sat for the senior certificate examination in biology, and very few of them who tried to attempt genetics questions were reported to respond poorly and also did poorly (WAEC, 2015 – 2021). Common problems identified by this examination body include students' confusion of basic terms that look- and sound-alikes such as gene and chromosome, allele and alleles, genotype and phenotype, and meiosis, and mitosis, among others). Also, identified were relatively little understanding of the concepts, poor application as well as misconceptions about the subject. In support of this, previous empirical research in biology in Nigeria for over two decades now has consistently confirmed that students lack a deeper comprehension of this aspect of biology (Jacob *et al*., 2020).

This poor understanding has been attributed to different factors by researchers. For instance, Ezeaghasi (2018) attributed this to the conceptual and practical difficulties in genetics concepts learning. This lack of understanding has been translated to their inability to apply the knowledge acquired in genetics to their everyday lives and related issues that arise and to actively participate in social-related issues and debates on this concept. Knippels *et al*. (2005) studies revealed that the major difficulties experienced by students include the genetics terminologies, problem aspects such as the Mendelian genetics crossing, the abstract, as well as the complex nature of genetics. In her study, Ezeaghasi (2018), attributed this to the negative perception of genetics as most of the students viewed the concept as being difficult and abstract in nature. Literature has reviewed that perception has a great influence on any biology concept students are learning in the classroom (Ezeaghasi, 2018;

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Akinola, 2003). However, Haruna (2021) and Etobro and Fabinu (2017) have attributed students' negative perceptions to the ways concepts in biology are taught (teaching strategies), the mathematical aspect of some concepts, lack of real practical contents, inadequate learning resources and students' attitude as well as learning habits, among others. While, Soe (2018) thought that only if the perception of students is positive about biology learning, their comprehension of biology concepts will be better.

Many researchers in the field of bioscience have also shown that students' perceptions in various parts of the world are often due to numerous misconceptions they hold about genetics concepts (Machová and Ehler, 2021). For instance, Haambokoma (2007) in Zambia, Suparyana (2014) in Indonesia, Tsui and Treagust (2007) in Australia, Marbach-Ad (2001) in Israel, Lewis, Leach and Wood-Robinson (2000) in the United Kingdom and Mills, Van Horne, Zhang and Boughman (2008) in the United States. Genetics is considered a difficult and confusing topic because of its abstract nature and has many alien terminologies; this often causes student understanding to differ from that of professionals based on theory and principles. This misunderstanding often referred to as misconception can be found in the meaning of genetics concepts, terminologies, genetic materials, principles of inheritance, mechanism of inheritance of traits, sex selection, and determination, as well as mutations, among others (Sarhim & Fauziyah, 2015; Suhermiati, 2015). This misconception has been attributed to several factors, such as mode of instruction, students-related and teachers-related factors, recommended textbooks, and genetics contents (Gusmalini *et al*., 2020) employed by biology teachers at this level of education. Others include students' poor imagination of different genetic concepts and processes in connection with their daily activities (Duncan & Reiser (2007), and poor interconnection of genetic concepts concerning the multiple biological organizations, thus leading to a disorganized mind map, which could result in a misconception and eventually poor comprehension of the concept (Lewis *et al*., 2000).

So far, the efforts to identify conceptual understanding, perception, and misconceptions about genetics concepts in secondary school students in Nigeria especially in Ondo have not been carried out. Therefore, there is a need for a design to distinguish students who know genetics concepts, lack knowledge of genetics, and misconception as well as students who have a positive perception, and do not have a positive perception of genetics concepts. To identify students' misconceptions of genetics concepts in this study (Hasan *et al*., 1999) Certainty Response Index (CRI) method was deployed. Based on this background, this study aims to identify the differences between students' lack of understanding and their misconceptions, as well as their perception of genetics concepts and the causes of misconceptions. Research questions are in the following:

(i) What are secondary school students' conceptual understandings of genetic concepts in biology?

(ii) What are secondary school students' perceptions of genetic concepts in biology?

(iii) What are the misconceptions secondary school students had about genetics concepts in biology?

(iv) Why do these secondary school students have misconceptions about genetics concepts in biology?

(v) What are the suggestions of secondary school students to avoid misconceptions about genetics concepts?

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2. METHODS

2.1. Research Design and Sample

In conducting this study, the mixed method design of sequential explanatory (QUAN + qual) was adopted. The population consisted of secondary school students from the existing three senatorial districts of Ondo State. This study employed the multistage procedures in selecting the sample for the study. Firstly, the simple random sampling technique was used to select a Local Government Area (LGA) from each senatorial district, making a total of three local government areas (X, Y, Z). After this, five secondary schools were randomly selected from each selected LGA, making a total of 15 secondary schools. Lastly, a purposive sampling technique was used to select senior secondary school three (SS 3) biology students from the selected 15 secondary schools. In all 789 (X-261, Y-258, Z-270) students took part in the study.

2.2 Research instruments

Data were collected using five instruments. They include:

(i) **Students' Genetics Concepts Test (SGCT):** The SGCT was self-constructed by the researcher to measure students' level of comprehension of genetics concepts under these themes (transmission and expression of characters in organisms, chromosomes and probability in genetics; sex-linked characters, sex determination and application of principles of heredity, and morphological and physiological variation). It consisted of 20 multiple-choice items with five options, ranging from options A to E, with one correct answer for each item and four distracters. Each correct answer to an item received one mark, while incorrect answers received zero marks, in all a total of 20 marks can be obtained by participating students. The validity of SGCT was carried out by giving copies to experts in biology education and test-item construction to ascertain suitability considering language, relevance, clarity of purpose, and precision. Out of the initial 35 items, 9 items were screened out remaining 26 items. Their suggestions were incorporated into the final draft of the instrument for reliability. The surviving 26 items were pilot-tested on SS 3 students who were not participants outside of the sample schools. The reliability was determined using Kuder-Richardson-20, and 0.78 was obtained. The 20 multiple-choice items were accomplished by the CRI scale.

(ii) **The Certainty Response Index (CRI) Scale:** The CRI was adopted from Hasan et al. (1999)'s Certainty Response Index. It was used to measure an individual degree of certainty in answering a given question by making use of scientifically proven knowledge. CRI was structured on a six-point scale (0–5) that is given along with each answer to a multiple-choice answer question, whereby the student's confidence in his/her ability to correctly answer the question is indicated in the provided CRI scale. A low CRI (for instance, 0–2), indicates guessing, regardless if the provided response was right or not, which means that such respondent lacks confidence in answering the question but determines the answer through guesswork. Equally, if the respondent displayed a high level of CRI (for instance, CRI of 3–5), this shows that he/she has a high confidence in the answer selected and this high level of confidence in the chosen answer was supported. Nevertheless, if the chosen response was not correct, this high level of confidence would mean that such respondent has false trust in his/her understanding of genetics concepts, this false trust is a sign of misconceptions. The CRI accompanied the SGCT which comprised 20 multiple-choice test items. The decision representation of CRI for a group of students concerning

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a given question/task is shown based on all the possible groupings of correct or incorrect/w responses with high or low CRI is presented in **Table 1**.

Table 1. Tests answer criteria for a group of students with a CRI scale.

Answer criteria (Score)	Low CRI (less than 2.5)	High CRI (greater than 2.5)
Correct Answer (1)	Right response but low CRI means do not understand the concepts	Right response with high CRI means understanding the concepts
Wrong Answer (0)	Wrong response with low CRI means do not understand the concept	Wrong response and high CRI mean a misconception

(iii) **Students' Perception of Genetics Concepts Questionnaire (SPGCQ):** The researcher constructed the SPGCQ to assess students' perception of genetics concepts in biology. The questionnaire had 25 items with a four-point Likert scale. The ratings for the items ranged from Strongly Agree-SA, Agree-A, Disagree-D to Strongly Disagree-SD. The positively constructed items were scored as SA - 4, A - 3, D - 2, and SD – 1, respectively, the negative items were reversely scored. The validity of SPGCQ was done by giving the initial 55 items on a four-type response to experts in genetics education to determine its suitability and applicability. Only thirty-seven (37) items survived scrutiny and were later trial-tested on thirty-one (31) SS 3 students who were not part of the sampled school. Cronbach's Alpha was used to establish its reliability. To obtain a reliability index that was good enough, 12 items were deleted. A reliability coefficient of 0.88 was obtained.

(iv) **Questionnaire on the Perceived Causes of Students' Misconceptions in Genetics Concepts (QPCSMGC):** The QPCDMGC was self-constructed by the researcher to assess the causes of misconceptions concerning genetics concepts. The questionnaire had 18 items constructed on a 4-point Likert scale with four indicators (genetics contents, students, teachers, and instructional materials). The ratings for the items ranged from Strongly Agree-SA, Agree-A, Disagree-D to Strongly Disagree-SD. The items were scored as SA - 4, A - 3, D - 2, and SD – 1, respectively. The face and content validity of SPGCQ was done by giving the initial 25 items on a four-type response to experts in biology education to determine its suitability in terms of clarity of ideas, language of presentation, class level, coverage, relevance, and application to the study. Only 21 items survived scrutiny and were trial-tested on thirty-one (31) SS 3 students who are not part of the sampled school. Cronbach Alpha was used to ascertain its reliability. To obtain a reliability index that was good enough, three items were deleted. A reliability coefficient of 0.81 was obtained.

(v) **Students Focus Group Discussions (SFGDs) Guide: The SFGDs had three sessions:** A, B, and C. Section A assessed students' demographic status. Sessions B and C contained items that assessed causes of misconceptions and suggestions to avoid misconceptions of genetics concepts, respectively. SFGDs were carried out on 20% of the respondents who participated in the study. 20% of the respondents were randomly selected from secondary schools. Thus, there were 52, 52, and 54 from LGAs (X, Y, and Z), respectively, making a total of 158 respondents from the selected 15 secondary schools.

2.3. Methods of Data Analysis

The quantitative data collected were analyzed using the descriptive statistics of mean, standard deviation, and simple percentages, while the qualitative data (students' focus group discussion session) were content analyzed (All verbal data were transcribed before analysis).

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3. RESULTS

3.1. Research Question 1: What are Secondary School Students' Conceptual Understandings of Genetic Concepts in Biology?

The data collected to answer this research question was subjected to a simple percentage analysis of the multiple-choice items based on the adopted CRI technique. Students' understanding level was categorized into understanding the concept and not understanding, while the students' concept understanding distribution for each genetics concept is presented in **Table 2**.

Table 2. Distribution of students' genetics concept understanding.

S/N.	Sub-content areas	Question number	Level of understanding		Misconceptions (%)
			Understand concept (%)	Do not Understand concept (%)	
1.	Transmission and expression of characters in organisms	1, 3, 6	15.2	27.7	57.1
2.	Chromosomes and Probability in Genetics	2, 4, 5, 7, 8, 9, 15	20.5	25.0	54.5
3.	Linkage, sex determination, and application of the principles of heredity	10, 11, 12, 13, 16, 17, 19, 20	17.7	30.3	52.0
4.	Morphological and physiological variation	14, 18	32.2	27.5	40.3
	Average (%)		21.4	27.6	51.0

Table 2 shows students' level of genetics concept understanding under understand, and do not understand categories. It was observed that 21.4% of the respondents understood genetics concepts, while 27.6% did not understand genetics concepts. This implies that few numbers of the respondents have a good grasp of the genetics concepts. **Table 2** further reveals the distribution of respondents under the two categories. In the category of do not understand, 30.3% of the respondents did not understand sex linkage, sex determination as well as application of the principles of heredity sub-content areas. It is followed by 27.7% in transmission and expression of characters in organisms, 27.5% in morphological and physiological variation, while 25.0% did not understand chromosomes and probability in genetics content areas. In the understanding category, 32.2% of the participants understood morphological and physiological variation, followed by 20.5% understood chromosomes and Probability in genetics, 17.7% understood Linkage, sex determination, and application of the principles of heredity, while transmission and expression of characters in organisms (15.2%) was the least understood concepts.

3.2. Research question 2: What are Secondary School Students' Perceptions of Genetic Concepts in Biology?

To answer this research question, the collected data were subjected to item analysis of mean and standard deviation, the result is presented in **Table 3**. Based on this result, the students' perception mean average was categorized into either positive or negative perceptions.

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Table 3. Students' perception of genetics concepts in biology.

S/N.	Items	Mean	SD
1	Genetic concepts are important for advancement in biology	2.51	0.81
2	Knowledge of genetics can be useful for finding cures for some diseases	2.58	0.72
3	Genetics makes our lives healthier	2.29	0.82
4	Genetics lessons are demanding	2.67	0.85
5	The benefits of genetics are greater than the harmful effects it could have	1.80	0.63
6	Knowledge of genetics helps to improve plant and animal production	2.53	0.71
7	Genetics is not useful for the society	2.65	0.84
8	Genetic concepts are controversial	2.67	0.96
9	A different application of genetics makes it complicated to understand	2.60	0.72
10	Learning genetics helps students relate genetics knowledge to real-life social issues	2.56	0.78
11	Genetic concepts are difficult to learn	2.77	0.79
12	Genetic terminologies are confusing to understand	2.78	0.88
13	The Mendelian aspect seems complicated to learn	2.72	0.95
14	Knowledge of genetics is necessary for understanding other concepts in biology better	2.31	0.83
15	Genetics-related issues make the concepts complex	2.56	0.76
16	Genetic contents are wide in nature	2.34	0.88
17	Genetic concepts are easy to learn	2.28	0.97
18	Genetics is relevant to our daily lives	2.45	0.75
19	Mendelian theories are easy to explain	1.73	0.68
20	The mathematical aspect of genetics requires a lot of time reading before understanding them	2.66	0.69
Weighted mean/Average SD. = 2.47/0.80			
Criterion mean = 2.50			

Table 3 indicated the weighted mean of 2.47, out of the maximum obtainable score of 4.00, which is higher than the criterion means of 2.50. This means that secondary school students have a negative perception of genetic concepts in biology.

3.3. Research Question 3: What are the Misconceptions Secondary School Students had about Genetics Concepts in Biology?

To answer this research question, the collected data were subjected to item analysis of mean and standard deviation, the result is presented in **Table 2**.

The results presented in **Table 2** revealed that 51.0% of the respondents on average had misconceptions about genetics concepts in biology. Table 2 also revealed the percentage distribution for the five sub-genetics content areas. Transmission and expression of characters in organisms has the highest number of students (57.1%) with misconception in genetics concepts, followed by Chromosomes and Probability in genetics with 54.5% of the respondents with misconception, 52.0% of the respondents had misconception with linkage, sex determination and application of the principles of heredity, while 40.3% of the respondents had misconception with morphological and physiological variation.

3.4. Research question 4: Why do these Secondary School Students have Misconceptions about Genetics Concepts in Biology?

Students' responses to the causes of misconception questionnaire which comprised four indicators namely genetics contents, students, teachers, and instructional materials were

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used for data collection. The collected data were analyzed using mean and standard deviation, while the result is presented in **Table 4.** This is buttressed by the content analysis of the responses to the given interview.

Table 4 shows different reasons adduced by senior secondary school students for the causes of their misconceptions about genetics concepts in biology. It was revealed that genetics contents were rated the highest by mean scores compared to the remaining three indicators, with a mean score of (2.92 > 2.50), out of the maximum obtainable score of 4.00, which is higher than the criterion mean of 2.50. This implies that genetics content is the major reason for students' misconception of genetics concepts. This was contributed to by the abstract nature of genetics concepts (3.14 >2.85) and complexity of genetics concepts (3.09 > 2.85) as they were with mean scores higher than the grand weighted mean of 2.85, respectively.

The genetics contents indicator was followed by both the teacher/school indicator and students' indicator (2.83 >2.50). The teacher/school indicator was contributed to by biology teachers' mode of instruction (3.26>2.85) and lack of practical classes while learning the concept of genetics (3.14 >2.85) as they were with mean scores higher than the grand weighted mean of 2.85, respectively.

The students' indicator was attributed to cultural and religious beliefs and practices, genetics involves several concepts that I cannot connect very well, and poor attitude to genetics learning with mean scores of 3.11, 2.86, and 2.85, respectively, which was higher than and equal to the grand weighted mean of 2.85, respectively.

The instructional materials indicator was the least with a mean score of 2.81 >2.50. This was contributed to by the unavailability of instructional materials in genetics concepts and available textbooks are not detailed with mean scores of 3.03 and 2.86, respectively, which were higher than the grand weighted mean of 2.85.

Table 4. Causes of misconception among students in genetics concepts.

S/No	Items	Mean	SD
A	**Genetic contents**		
1	Abstract nature of genetics concepts	3.14	1.05
2	Interdisciplinary nature of genetics concepts	2.74	1.02
3	Complexity of genetics concepts	3.09	1.02
4	Genetics contained terminologies that are difficult to understand	2.71	1.11
	Weighted mean = 2.92		
B	**Students**		
5	Poor attitude to genetics learning	2.85	1.11
6	Prior knowledge of students about the genetic concept	2.54	1.02
7	Memorization of some concepts in genetics	2.78	1.10
8	Genetics involves several concepts that I cannot connect very well	2.86	1.17
9	Cultural and religious beliefs and practices	3.11	1.08
	Weighted mean = 2.83		
C	**Teacher/School**		
10	Biology teachers' mode of instruction	3.26	1.03
11	Biology teachers' competency in genetics concepts	2.62	1.14
12	Lack of practical classes while learning the concept of genetics	3.14	1.05
13	Deliberate skipping of some genetics concepts by biology teachers	2.67	1.09
14	Limited time to teach various genetics concepts	2.56	1.16
15	Non-applicability of content taught in the genetics classes	2.74	1.15

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Table 4 (Continue). Causes of misconception among students in genetics concepts.

S/No	Items	Mean	SD
D	**Weighted mean = 2.83**		
16	Available textbooks are not detailed	2.86	1.12
17	Sequence of genetics topics presentation in the textbooks	2.64	1.04
18	Unavailability of instructional materials in genetics concepts	3.03	0.98
	Weighted mean = 2.84		
	Grand Weighted mean/Average Std Dev. = 2.85		
	Criterion mean = 2.50		

3.4. Research question 5: What are the Suggestions of Secondary School Students to Avoid Misconceptions about Genetics Concepts?

Students' responses to the student focus group discussion session on the suggestions to avoid misconceptions were used for data collection. The collected data were content analyzed, and the result was presented as follows:

"Majority of the students indicated that genetics concepts should be taught earlier than the time it was slated on the school timetable which is closer to their Senior Secondary School Examinations. The majority of them also suggested that more practical hours/time should be allocated to the teaching of the concept on the timetable and that the biology textbooks to be recommended must be detailed and written in a simple language for easy understanding."

"Some of them indicated that their biology teachers need to engage them more in the genetics classroom. They suggested that their biology teachers should make use of instruction mediums that are interactive in nature which will make them active, contribute, and discuss genetics concepts with themselves. They also suggested that genetics concepts should be situated more to their learning environment as most of the illustrations or examples given were foreign in nature".

4. DISCUSSION

4.1. Secondary School Students' Conceptual Understandings of Genetic Concepts in Biology

The results revealed that 21.4% of the respondents understood genetics concepts, while 27.6% did not understand genetics concepts This implies that few numbers of respondents have a good grasp of the genetics concepts. This is in line with the findings of Machova and Ehler (2021) and Opfer *et al*. (2012) that most secondary school students did not have a good understanding of genetics concepts. It was also supported by the findings of Ezeaghasi (2018) who found that students have difficulties in comprehending genetics concepts. This difficulty in understanding the terms contained in genetics concepts may be due to the complexity and abstraction of the topic which may make it hard to grasp in detail. Also, it is a topic that involves several biological organizations which may make it difficult for students to relate to each concept very well (Duncan & Reiser, 2007).

4.2 Secondary School Students' Perception of Genetic Concepts in Biology

The results indicated that secondary school students have a negative perception of genetics concepts in biology. This negative perception of genetics concepts may be due to students' difficulty in connecting related socioscientific issues with what they learned in the genetics classroom. Most of them believed that the knowledge of genetics is not relevant when learning other concepts in biology and that the application aspect is complicated to

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understand. In addition, it may also be attributed to their inability to understand the terminologies involved as well their general belief that the concepts are difficult to learn and apply to their day-to-day activities. This result of negative perception was supported by the findings of Ezeaghasi (2018) who found that genetics was one of the concepts students perceived to be complex and abstract in nature, and has a great influence on any biology concept students are learning in the classroom. In the same vein, this result follows the WAEC Chief Examiner's Report on biology theory questions, that among biology questions, genetics questions were unpopular among the candidates and that very few candidates attempted them. It was reported that those who attempted them did not respond well to the questions because they had poor comprehension of the concept.

4.3 Misconceptions About Genetics Concepts in Biology

The results showed that on average, more than half of the students had misconceptions about genetics concepts in biology. This result is supplemented by the findings of Gusmalini *et al.* (2020), who in their study identified that about 42.1% of the respondents had misconceptions about the genetics concept, while 37.8% understood it, and 22.4% did not understand the subject. This result is in line with the findings of Etobro and Banjoke (2017) that 75.1% of the average student teachers had misconceptions about genetics concepts. Most of the students have misconceptions about the transmission and expression of characters in organisms, chromosomes, and probability in genetics, linkage, sex determination, and application of the principles of heredity. This result follows the findings of Osman *et al*. (2017) and Yates and Marek (2013) that students have misconceptions about various subtopics in genetics. Similarly, Pontarotti *et al*. (2022) indicated that students' misconceptions of genetics concepts include terminologies of genetics, application of genetics (Mendelian) theories, chromosomes, and determination of sex. Also, supported by the findings of Pashley (2010) who revealed that students often find it difficult to differentiate between genes and alleles.

4.4 Reasons for These Misconceptions About Genetics Concepts in Biology

The results indicated that genetic contents are the major reason for students' misconceptions about genetics concepts. This may be due to the abstract and complex nature of the genetics concepts. In line with this, the result of Frederick-Jonah and Tobi (2022) indicated that genetics is difficult due to the abstraction of its sub-concepts. It is in line with the findings of Duncan and Reiser (2007) who attributed the causes of difficulty in genetics learning for students to the hiddenness and remoteness of genetic processes, as well as the complex nature of the concept. Also, according to Haambokoma (2007), genetics concepts have too many terms that look-alike and sound-alike like allele, alleles, phenotype, and genotype, and this gets students confused.

4.5 Suggestions to Avoid Misconceptions About Genetics Concepts

The results revealed that the teacher/school, students, and instructional materials indicators were also indicated by the students as the reasons for the misconception they had about genetics concepts. These may be attributed to the strategies employed by biology teachers, limited practical activities, cultural and religious practices, negative attitudes of students to the concept, unavailability of teaching materials, and undetailed textbooks. This result is in line with the other research findings (Mahmud & Bature, 2017) that inappropriate modes of instruction adversely influenced the comprehension of genetics concepts and some difficult topics in science, respectively. In line with this present result, Haambokoma (2007)

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found that the speed of lesson presentation, inadequate time, lack of learning resources, and practical activities are some of the causes of misconceptions in genetics concepts. This result is in line with the findings of Chen *et al*. (2016) who observed that students show a negative attitude toward some aspects of genetics such as cloning of human cells, sex determination, and selective abortions. Cimer (2012) reported that secondary school students have negative attitudes toward genetics as a result of teachers' style of teaching biology. Also supported by the findings of Venville and Treagust (2002) that students often had problems relating subtopics in genetics concepts. In addition, Marbach-Ad (2001) indicated that students cannot connect some terminologies like genes and DNA, traits, and characters.

4.6 Secondary school students' focus group discussion sessions

The quantitative result above was supported by the result from the student's focus group discussion sessions, which were subjected to content analysis. The result revealed that:

"Most of the respondents indicated that most of the recommended biology textbooks were not detailed enough, as most of them do not structurally and functionally distinguish chromosomes, genes, and DNA from each other. And also, they failed to relate topics together, as a result of this, we find it difficult to link some topics and conceptualize them".

"Some of them revealed that their biology teachers only convey learning material theoretically with no support from laboratory sessions and examples that are related to their daily life activities. While some of their teachers referred them to materials in the textbooks as they were asked to read up. They were also of the view that most of them do not re-study given materials by the teacher and did not do or complete given assignments".

"Most of the respondents thought that biology is a wide subject in terms of contents. Due to time limitations, the large number of contents were tried to be covered by their teachers, leaving less time for teaching some important topics like genetics. They further indicated that the placement of genetics concepts at the end of the SS3 biology syllabus when they were about to start their Senior School Certificate Examination (SSCE) examinations did not afford them time to study the concepts".

"They were of the view that most of the terminologies are abstract in nature and confusing such terms as gene, allele, chromosome, chromatid, and chromatin. Some of them from their religion end believed that the time and the location during sexual intercourse may lead to having an albino child in the family. While some culturally, believed that an albino is a bastard child in the family. Most of them also believed that people of the same surname, relatives, and those who resemble their parents all have the same genetic makeup".

5. CONCLUSION

We analyzed and examined secondary school students' conceptual understanding, perceptions, and misconceptions about genetics concepts. It can be concluded that only 21.4% of the students understood genetics concepts. Secondary school students' perception of the genetic concepts in biology was negative. More than average of the students have misconceptions about genetics concepts in biology, while transmission and expression of characters in organisms were the most mis-conceptualized genetics concepts. Genetics contents were the major cause of students' misconception of genetics concepts in terms of the abstract and complex nature of genetics concepts. Also, biology teachers' mode of instruction, lack of practical classes, culture, and religious beliefs and practices, inability to connect several genetics concepts, poor attitude to genetics learning, unavailability of instructional materials as well as undetailed available textbooks were other major causes of students' misconceptions. It was suggested by the students that the learning of genetics

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concepts should be situated more to their learning environment. The following recommendations were made:

(i) The teaching and learning of genetics concepts should be supported with relevant instructional materials and detailed textbooks that have been evaluated by experts in the field to be detailed and often activities-oriented

(ii) The culture and religious beliefs as well as practices of students must be considered when planning and implementing genetics lessons, to correct any misconceptions that may arise from these practices.

(iii) Biology teachers should adopt innovative and issues-based strategies that can integrate socioscientific issues into the teaching and learning of genetics concepts and create opportunities for students to discuss their ideas and engage with practical activities. This can help them break down what is wrong and right about their misconceptions as well as actively construct and reconstruct their knowledge with the discussions.

(iv) Genetics is one of the biology concepts that deals with a lot of practical.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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