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Examination of secondary school students' conceptual understanding, perceptions, and misconceptions about genetics concepts

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ABSTRACT

Genetics concepts is taught at secondary school to equip students with relevant knowledge to engage with related socio-scientific issues in order to make a reasonable decision. However, earlier research shown that students exhibited poor comprehension of this concept. Despite several interventions, this problem persists. This study was designed to examine senior school students' conceptual understanding, perceptions and misconceptions about genetics concepts as well as the causes of the misconceptions identified. The mixed methods design was adopted, while 789 students participated. Five instruments were used, while data collected were descriptively and content-analyzed. The results revealed that 21.4% of the students understood genetics concepts, 27.6% did not, while 51.0% had misconceptions. Students had negative perception of genetics concepts ($\bar{x}$=2.47) and genetics contents indicator was the major causes of students' misconceptions ($\bar{x}$=2.92) against the 2.50 threshold. The teaching and learning of genetics concepts should be supported with relevant instructional materials and detailed textbooks.

Keywords: conceptual understanding, perceptions, misconceptions about genetics

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. This biology concept is also central for understanding some controversial issues related to genetics such as cloning, genetically modified organisms (GMOs), 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 GMOs, fingerprinting, genetic diseases, cloning, gene therapy is widespread among us. This progress makes it an important concept that every citizen must understand in order to make informed choices in their lives, and also shows why genetic education is essential than before in the school biology curriculum (Vlčková et al., 2016). Nigeria Federal Ministry of Education understood this need, and make 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 transfer, as well as the variation, functions and behaviors of genes. The sub-topics found under genetics in Nigeria 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. Furthermore, genetics instruction at secondary school also aided students progression from simple concepts comprehension to more sophisticated levels of understanding, and allowed integration of newly learned content into their previous understandings, and this can help students comprehend important issues in society as a result of the application of genetics knowledge such as genetic testing for diseases and genetically modified foods (Cisterna et al., 2013), in order to be informed, and make a reasonable decision.

However, despite the importance of genetics, Chief examiner's report for West Africa Examination Council (WAEC) Nigeria on 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–alike such as gene and chromosome, allele and alleles, genotype and phenotype, meiosis and mitosis, among others). Also, identified were relatively little understanding of the concept, poor application as well as

misconceptions about the genetics concepts. In support of this, previous empirical research in biology especially in Nigeria for over two decades now have being consistently confirmed that students lack a deeper comprehension of this aspect of biology.

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 knowledge acquired in genetics to their everyday lives and related issues that arise, and to actively participate in social-related issues debates in this concept. Buske and Bartholomei-Santos (2019) study revealed that the major difficulty experienced by students is the aspect of the Mendelian inheritance. In her own study, Ezeaghasi (2018) attributed this to the negative perception of genetics as most of the students viewed the concept has been difficult and abstract in nature. Furthermore, Ezeaghasi (2018), attributed students' negative perception to ways concepts in biology are taught (teaching strategies), mathematical aspect of some concepts, lack of real practical of contents, inadequate learning resources and students' attitude as well as learning habits, among others. While Soe (2018) was of the opinion that only if the perception of students is positive to biology learning, their comprehension of biology concepts will be better.

Many researchers in the field of bioscience have also showed that students' perception in various parts of the world is often due to numerous misconceptions they hold about genetics concepts. For instance, Kilic et al. (2016) in England and Turkey, Machová and Ehler (2023) in Czech Republic, Osman et al. (2017) in Lebanon, and Tammu (2022) in Indonesia, among others.

Genetics is considered difficult and confusing topic because of its abstract nature and has many alien terminologies; this often causes student understanding to differs from that of professionals call 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 of traits, sex selection and determination, as well as mutations, among others. 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 confusion of the terms genes and alleles, which in turn creates difficulty in understanding the terms recessive and dominant (Abraham et al., 2014), and poor interconnection of genetics concepts (Cisterna et al., 2013), may thus leads to students inability to transfer knowledge gained in genetics concepts, which could result in misconception and eventually poor comprehension of genetics concepts.

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 has the knowledge of genetics concepts, lacks knowledge of genetics, and misconception as well as student who has positive perception, and do not have positive perception of genetics concepts. In order to identify students' misconception in genetics concepts in this study, Hasan et al.'s (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 misconception, as well as their perception of genetics concepts and causes of misconceptions.

Research Questions

RQ1. What are secondary school students' conceptual understandings of genetic concepts in biology?

RQ2. What are secondary school students' perception of genetic concepts in biology?

RQ3. What are misconceptions secondary school students had about genetics concepts in biology?

RQ4. Why do these secondary school students have misconceptions about genetics concepts in biology?

RQ5. What are suggestions of secondary school students to avoid misconceptions about genetics concepts?

MATERIALS & METHODS

Research Design & Sample

In conducting this study, the mixed methods 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 procedure 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 LGAs (X, Y, and Z). After which, five secondary schools were randomly selected from each selected LGA, making a total of 15 secondary schools. Lastly, 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, and Z-270) SS 3 students took part in the study.

Research Instruments

Data were collected using five instruments. These include the followings:

1. Students' genetics concepts test (SGCT)
2. CRI scale
3. Students' perception of genetics concepts questionnaire (SPGCQ)
4. Questionnaire on perceived causes of students misconceptions in genetics concepts (QPCSMGC)
5. Students' focus group discussions (SFGDs) guide

Table 1. Tests answer criteria for group of students with 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 concepts	Right response with high CRI means understands concepts
Wrong answer (0)	Wrong response with low CRI means do not understand conception	Wrong response & high CRI means a misconception

Students' genetics concepts test

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 mark, in all a total of 20 marks can be obtained by participating student.

The validity of SGCT was carried by given copies to experts in biology education and test-item construction to ascertain the suitability considering language, relevance, clarity of purpose and precision. Out of the initial 35 items, nine items were screened out remaining 26 items. While their suggestions were incorporated to the final draft of the instrument for reliability. The survived 26 items were pilot tested on SS 3 students that were not participants outside of the sample schools. The reliability was determined using Kuder-Richardson-20, 0.78 was obtained. The 20 multiple choice items were accomplished by CRI scale.

Certainty response index scale

CRI was adopted from Hasan et al.'s (1999) CRI. 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 one's confident in his/her ability to correctly answer the question is indicted in the provided CRI scale. While a low CRI (for instance, 0-2), indicates guessing, regardless of if the provided response was right or not, which means that such respondent lacks confidence in answering the question but determined 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 answer selected and this high level of confident in the chosen answer was supported. Nevertheless, if the chosen response was not correct, this high level of confident would mean that such respondent has false trust in his/her understanding of genetics concepts, this false trust is a sign of misconceptions. CRI accompanied SGCT, which comprised 20 multiple-choice test items. The decision representation of CRI for a group of students in respect to a given question/task is shown based on all the possible groupings of a correct or incorrect/w responses with high or low CRI is presented in **Table 1**.

Students' perception of genetics concepts questionnaire

The researcher constructed 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 31 SS 3 students that are not part of the sampled school. Cronbach's alpha was used to established its reliability. In order to obtained reliability index that was good enough, 12 items were deleted, while the remaining 15 items were used for data collection. The reliability coefficient of 0.88 was obtained.

Questionnaire on perceived causes of students misconceptions in genetics concepts

QPCDMGC was self-constructed by the researcher to assess the causes of misconceptions among in respect to genetics concepts. The questionnaire had 18 items constructed on a four-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, dsagree-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 31 SS 3 students that are not part of the sampled school. Cronbach's alpha was used to ascertain its reliability. In order to obtained reliability index that was good enough, three items were deleted, while the remaining 18 items were used for the study. The reliability coefficient of 0.81 was obtained.

Students focus group discussions guide

SFGDs had three sessions of A, B, and C. Section A assessed students' demographic status. While session B and session C contained items that assessed causes of misconceptions and suggestions to avoid misconceptions about genetics concepts, respectively. SFGDs was carried out on 20.0% of the respondents who participated in the study. This 20.0% (158) of the respondents were randomly selected from the participating 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.

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 & expression of characters in organisms	1, 3, & 6	15.2	27.7	57.1
2	Chromosomes & probability in genetics	2, 4, 5, 7, 8, 9, & 15	20.5	25.0	54.5
3	Linkage, sex determination, & application of principles of heredity	10, 11, 12, 13, 16, 17, 19, & 20	17.7	30.3	52.0
4	Morphological & physiological variation	14 & 18	32.2	27.5	40.3
Average (%)			21.4	27.6	51.0

Table 3. Students' perception of genetics concepts in biology

S/N	Items	Mean	SD
1	Genetics concepts are important for advancement in biology	2.51	0.81
2	Knowledge of genetics can be useful for finding cures to 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 improving plant and animal production	2.53	0.71
7	Genetics is not useful for the society	2.65	0.84
8	Genetics concepts are controversial in nature	2.67	0.96
9	Different application of genetics makes it complicated to understand	2.60	0.72
10	Learning of genetics help students relate genetics knowledge to real life social issues	2.56	0.78
11	Genetics concepts are difficult to learning	2.77	0.79
12	Genetics 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 in nature	2.56	0.76
16	Genetics contents is wide in nature	2.34	0.88
17	Genetics concepts are easy to learning	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 of reading before understanding them	2.66	0.69

Note. SD: Standard deviation; Weighted mean/average standard deviation=2.47/0.80; & Criterion mean=2.50

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 discussions session) were content-analyzed (all verbal data were transcribed before analysis).

RESULTS

Research Question 1. What Are Secondary School Students' Conceptual Understandings of Genetic Concept in Biology?

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

Table 2 showed 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. **Table 2** further revealed 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., 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.

Research Question 2. What Are Secondary School Students' Perception of Genetic Concept in Biology?

In order 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 perception. **Table 3** indicated the weighted mean of 2.47, out of the maximum obtainable score of 4.00, which is higher than the criterion mean of 2.50. This means that the respondents have negative perception of genetics concepts in biology.

Table 4. Causes of misconception among students in genetics concepts

S/N	Items	Mean	SD
A	**Genetics 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 genetics 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	Culture and religion 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 of 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 teaching various genetics concepts	2.56	1.16
15	Non applicability of content taught in the genetics classes	2.74	1.15
	Weighted mean=2.83		
D	**Instructional materials**		
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		

Note. SD: Standard deviation; Grand weighted mean/average standard deviation=2.85; & Criterion mean=2.50

Research Question 3. What Are Misconceptions Secondary School Students Had About Genetics Concepts in Biology?

In order 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**. The results presented in **Table 3** revealed that 51.0% of the respondents on the average had misconceptions about genetics concepts in biology. **Table 3** also revealed the percentages 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.

Research Question 4. Why Do These Secondary School Students Have Misconceptions About Genetics Concept in Biology?

Students' responses on the causes of misconception questionnaire, which comprised four indicators namely genetics contents, students, teachers and instructional materials were 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** showed different reasons adduced by senior secondary school students for the causes of their misconceptions in genetics concepts in biology. It was revealed that genetics contents was 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 contents is the major reason for students' misconception in 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 contributed to by culture and religion 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 mean score of 2.81>2.50. This was contributed to by 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.

Research Question 5. What Are Suggestions of Secondary School Students to Avoid Misconceptions About Genetics Concepts?

Students' responses to the students focus group discussions session on the suggestions to avoid misconceptions were used for data collection. The collected data were content analyzed, and the result 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. Majority of them also suggested that more practical hour/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 writing 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 medium that interactive in nature that 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 illustration or examples given were foreign in nature."

DISCUSSION

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 the respondents have a good grasped of the genetics concepts. This is in line with the findings of Machová and Ehler (2021) 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 complex and abstraction of the topic, which may make it hard to grasp in detail and also it is a topic that involves several biological organizations, which may makes it difficult for students to connect concepts in genetics very well (Cisterna et al., 2013).

The results indicated that secondary school students have negative perception of genetics concepts in biology. This negative perception of genetics concepts may be due to students difficulty in connecting related socio-scientific issues with what they learnt during 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 understanding. 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 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 is in accordance with 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 have poor comprehension of the concept (WAEC, 2015-2018).

The results showed that on the 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 in genetics concept, while 37.8% understood it, while 22.4% did not understand the subject. Most of the students have misconception in transmission and expression of characters in organisms, chromosomes and probability in genetics, linkage, sex determination and application of the principles of heredity. This result is in accordance with the findings of Osman et al. (2017) that students have misconception about various subtopics in genetics. Similarly, Duda et al. (2021) indicated that students' misconception in genetics concepts include terminologies of genetics, application of genetics (Mendelian) theories, chromosome, and determination of sex. Also, supported by the findings of Abraham et al. (2014) who revealed that students often find it difficult to differentiate between gene and allele.

The results indicated that genetics contents are the major reason for students' misconception about genetics concepts. This may be due to the abstract and complexity nature of the genetics concepts. In line with this, the result of Mussard and Reiss (2022) indicated that genetics is difficult due to the abstraction of its sub-concepts as students find it difficult to connect ideas from different topics such as 'Punnett square' and 'DNA'. Also, in accordance with Abraham et al. (2014) that genetics concepts have too many terms, which look-alike and sound-alike like allele, alleles, phenotype, genotype, and this get students confused.

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, culture and religion practices, negative attitude of students to the concept, unavailability of teaching materials and undetailed textbooks. This result is in line with the findings of Mahmud and Bature (2017) that inappropriate mode of instructions adversely influenced the comprehension of genetics concepts and some difficult topics in science, respectively. In line with this present result, Cisterna et al. (2013) indicated that students, tended to struggle in distinguishing genes, chromosomes, and DNA and had some difficulties connecting the cell division process with the inheritance of genetic material. This result is in line with the findings of Chen et al. (2016) who observed that students show negative attitude to some aspects of genetics such as cloning of human cell, sex determination and selective abortions.

The quantitative result above was supported by the result from the students focus group discussions sessions, which was 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 topic and conceptualize them."

> "Some of them revealed that their biology teachers only convey learning material theoretically with no support by 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 assignment."

"Most of the respondents thought that biology is a wide subject in term of contents. Due to time limitation, large number of contents were tried to be covered by their teachers, leaving lesser time for teaching some important topics like genetics. They further indicated that the placement of genetics concepts at the end of SS3 biology syllabus when they were about to start their senior school certificate examination 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 like gene, allele, chromosome, chromatid, chromatin. While 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."

CONCLUSIONS

It can be concluded that only 21.4% of the students understood genetics concepts. Secondary school students' perception about genetic concept in biology was negative. More than average of the students has misconceptions about genetics concepts in biology, while transmission and expression of characters in organisms was the most mis-conceptualized genetics concepts. Genetics contents was the major cause of students' misconception in genetics concepts in terms of the abstract and complexity nature of genetics concepts. Also, biology teachers' mode of instruction, lack of practical classes, culture and religion 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 concepts should be situated more to their learning environment.

Recommendations

The following recommendations were made:

1. The teaching and learning of genetics concepts should be supported with relevant instructional materials and detailed textbooks that have been evaluated by expert in the field to be detailed and often activities oriented
2. The culture and religion beliefs as well as practices of students must be considered when planning and implementing genetics lesson, in order to correct any misconceptions that may arise from these practices.
3. Genetics is one of the biology concepts that deals with a lot of practical, more time should be allocated.

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Ethical statement: The authors stated that the research presented in this article has been conducted in accordance with the highest ethical standards and guidelines. Names of the participants, their schools and locations or any information about the participants are not revealed to the public domain through the study. Any personal information that can be used to identify participants was not included on the instruments. A consent letter explaining the purpose and outline of the research was given to the participants. Participation was strictly voluntary. The participants were made aware of the academic benefits of the research, and the confidentiality of the data to be collected. Data collected from the participants was used only for the purpose stated for in this study. The authors further stated that the researcher maintained the databases so that the research could be audited by interested parties. This was done to enable the reader to make independent judgements concerning the qualities of the analysis. Auditability was provided for replication and promotes rigour in both data collection and data analysis. To enable auditability, the documentation was kept confidential and safe, following data collection, thus promoting reliability and validity.

Declaration of interest: No conflict of interest is declared by the author.

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