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# Identification of Alternative Conceptions of Genetics held by Senior School Students in Ilorin, Nigeria, Using a Three-Tier Diagnostic Test

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## 1. Introduction

Students bring to lessons a lot of pre-existing (alternative) conceptions about scientific phenomena that can interfere with students' learning of correct scientific concepts (Gurel, Erylimaz & McDermott, 2015). Alternative conceptions are false or non-scientific beliefs held by students on a specific concept or phenomenon, which may be caused by their misunderstanding of other subjects or gained from their earlier experiences (Abdulwali & Alshaya, 2012). Alternative conceptions related to biology concepts are widely spread among students at every level of educational ladder and it represents a real barrier to students' understanding of biology (Bello, Bello & Abimbola, 2016). Alternative conceptions have been reported in most topics (genetics, ecology, respiration and photosynthesis) and across several educational levels (Taber, 2009).

Genetics as a concept in biology was coined in 1906 by Dilliam Bateson and it is defined as the study of heredity and variation. Genetics is one area of science and biology that needs to be understood generally. Most popular significant advancement in science and technology in this present time are from the knowledge of genetics. The role of genetics in human health and reproduction has made it a scientific discipline that everyone needs to understand. Yet, several studies reveal that students fail to critically understand the genetics knowledge taught in the classroom, and this lack of understanding leads to an inability to apply basic knowledge to their daily lives (Lewis & Wood-Robinson, 2000). Genetics is a biological concept in which students have understanding that is not aligned with biological theory (Lewis & Kattmann, 2004).

The West African Examinations Council Chief Examiners reported poor performance of biology students on genetics-related questions in biology examination "May/June 2015: poor response to questions on *genetics*; Nov/Dec 2013: inability to answer questions in *genetics* perfectly; May/June 2012: poor understanding of certain *genetic* terms e.g. nucleotide and hybrid". Several reasons have been discovered to cause the poor performance of students in biology by researchers. One of the reasons is alternative conceptions of science concepts held by students (Abimbola, 2013; Bahar, 2003).

Several evaluating methods such as Concept maps, multiple-choice tests, and interviews have been employed to determine students' alternative conceptions of science concepts and have proved to be successful methods however each has its limitations. As a result of these limitations, (Chandrasegaran, Treagust & Mocerino, 2007) reported that multiple-choice test item which include options that serve as reasons for students' responses was proposed. This led to two-tier and three-tier multiple-choice diagnostic tests mainly for identifying students' conceptions (scientific conceptions,

alternative conceptions and misconceptions) in limited and clearly defined content area. The first-tier of three-tier tests consist of multiple-choice questions, the second-tier deals with the reason for the response in the first-tier and the third-tier involves questions to measure the degree of confidence of the students' responses. This is used by many researchers (Caleon & Subramaniam, 2010) because it distinguishes a lack of knowledge from an alternative conception (Arslan, Cigdemoglu & Moseley, 2012). Dusica, Tamara, Mirjana and Sasa (2015) stated that there are only a few studies examining students' alternative conceptions in science using three-tier tests available in literature.

As a result of the limited three-tier diagnostic test in the literature despite its effectiveness in assessing students' alternative conceptions of scientific concept, this study aims at identifying alternative conceptions of genetics held by senior school students in Ilorin, Nigeria, using a three-tier test.

## 2. Theoretical Framework

The theoretical basis of this study is a constructivist approach that is grounded in the belief that learners' prior knowledge is a dominant factor in determining the outcomes of learning (Ausubel, 1968).

Constructivism is a theory of knowledge which argues that humans generate knowledge and meaning from an interaction between their experiences and their ideas. Piaget formulated the theory of constructivism and further explained processes by which knowledge is internalized by learners. Individual develop new knowledge from their prior experiences through the processes of accommodation and assimilation (Piaget, 1967).

The constructivist research programme has drawn attention to the way students' existing ideas complicate teaching. Where students come to class with their own alternative conceptions about science topics, this can often mean that even a teaching presentation that is effectively planned from the perspective of the conceptual structure of science (biology, chemistry, physics), may be wrongly understood because the learners interpret teaching in terms of their existing ways of thinking (Taber, 2009).

The concept of genetics can be characterized as abstract. Abstract concepts are hard to understand, which may in turn cause alternative conceptions which are hard to change therefore, students need to have high operational abilities in order to understand abstract concepts (Piaget, 1971). Ausubel indicated that effective learning involves constructing conceptual understanding in a meaningful way and further suggested that meaningful learning takes place if the learning task can be related in a concrete, substantive way to what the learner already knows. An early priority for the constructivist research programme was to find out a lot more about how students understood scientific concepts (Taber, 2009).

Constructivist approach suggests that learning build upon the cognitive and conceptual resources available. This results to a number of key constructivist principles for teachers:

- Teaching entails activating relevant prior ideas of learners to construct new ones.
- Students construct their knowledge based on partial, incorrect or irrelevant prior knowledge except carefully guided.

Students often have their own ideas on a topic which they acquired from other sources such as family, friends, media etc. This is being explored in science learning, where examples of 'misconceptions, alternative conceptions, preconception, intuitive theories, and alternative conceptual frameworks' that students acquired and are inconsistent with school science have been reported (Duit, 2009; Taber, 2009).

Since students' understanding of teaching will be based on their existing knowledge and way of thinking on a topic, teachers therefore need to diagnose students thinking effectively, so that teacher can channel that thinking towards the knowledge presented in the curriculum (Brock, 2007). Where teaching is not designed to closely build upon learners' current state of knowledge, many things can go wrong-misinterpretation, failure to make expected links, making inappropriate links, alternative conception (Taber, 2001).

This study is related to the theory of constructivism as it has been reported in the various studies that misconceptions and alternative conceptions are developed by students during the process of constructing their own meaning of the information given in a class. Constructivists are of the opinion that knowledge is acquired recursively, that is sensory data is combined with prior knowledge to create new cognitive structures, which result to the basis for further construction. Knowledge is also created cognitively by reflecting on prior knowledge and since each student brings a different cognitive framework to lesson and each will construct new knowledge in a different manner, different conceptions are developed which may be referred to as misconceptions and alternative conceptions.

## 3. Research Method

This research adopted descriptive research of the survey type. It involved 281 senior secondary school III students offering biology in 12 selected schools. The multiple-choice "Genetic Concept Diagnostic Tool" (GCDT), a 14-question instrument was developed through three stages: (1) adaptation of GCDT from the paper works of Tsui (2002), Elrod (2007) and Moskalik (2007), (2) validation of GCDT, (3) pilot study.

The GCDT was administered to the participants as three-tier test. As shown in the following Table 1, the first-tier consist of multiple-choice questions about genetics content, the second-tier deals with the reason for the response in the first-tier in which one alternative conception was imbedded and the third-tier measure the degree of confidence of the students' responses.

**Table 1: Sample Question from Genetic Concept Diagnostic Tool (GCDT)**

| Sample Question-1 |
|---|
| What is the chemical composition of DNA?<br>traits (B) nucleotides (C) amino acid (D) alleles<br><br>Reason for your answer: because they<br>are nitrogenous base<br>require energy from the cell<br>made of organic compound<br>are strand<br>Are you sure?<br>i. Yes, I am sure ii. No, I am not sure |

### 3.1 Validation of Research Instrument

The validity of GCDT was done by given it to two lecturers in the Department of Science Education, University of Ilorin, two lecturers in the Department of Plant Biology, University of Ilorin and one experienced biology teacher. A pilot study was performed with 20 senior secondary school III students offering biology, which were separate from the study group. The pilot study of GCDT was accomplished by conducting item analysis. Item discrimination indices ranged between 0.2 and 0.8 with an average of 0.307, item difficulty indices ranged between 0.55 and 0.9 with an average of 0.515. Kuder-Richardson 20 (KR-20) formula was used to check the internal consistency reliability of the test and KR-20 coefficient was found to be 0.95 indicating that the items functioned in a satisfactory way.

## 4. Results

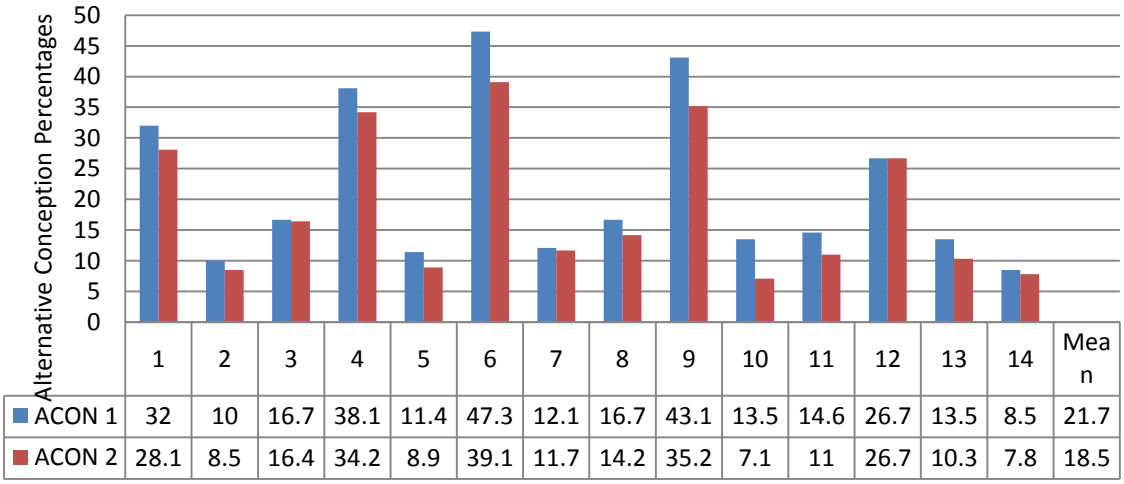
In analyzing GCDT data, when 111 coding was obtained as a result of selection of correct choice in the first-tier, second-tier and selection of Yes, I am sure in the third-tier the students were considered to have correct conception but if alternative option was selected at the second-tier and Yes, I am sure in the third-tier, the students were considered to have alternative conception.

Figure 1 represents the alternative conception percentages with respect to the number of tiers for SSS 3 students. All items are represented by bar graphs for the ACON1 and ACON2, and are represented by different colors. The first bar

identifies the ACON1 values and second bar identifies ACON2 values. Figure 2 shows that the ACON1 values are higher than the ACON2 values. Therefore, the percentages decrease from the second-tiers to the third tiers. For the items that students have strong alternative conceptions about (question numbers 1, 4, 6, 9, 12), the COR3 values varied between 1.8% and 11.7%, which were low. The alternative conceptions of the SSS 3 students with percentages above 18.5% mean score are presented in Table 2. The highest value of the ACON2 belongs to Question 12, "Which one of the following concisely describe gene?" with a value of 38.4% and very low COR3 of 1.8%.

Alternative Conception in Second Tier (ACON1): The percentage of alternative conception choices "1-2's" for each item.

Alternative Conception in Third Tier (ACON2): The percentage of alternative conception choices "1-2-1's" for each item.




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACON 1 | 32 | 10 | 16.7 | 38.1 | 11.4 | 47.3 | 12.1 | 16.7 | 43.1 | 13.5 | 14.6 | 26.7 | 13.5 | 8.5 | 21.7 |
| ACON 2 | 28.1 | 8.5 | 16.4 | 34.2 | 8.9 | 39.1 | 11.7 | 14.2 | 35.2 | 7.1 | 11 | 26.7 | 10.3 | 7.8 | 18.5 |

Figure 2: Three-tier Alternative Conceptions of SSS 3 Students

Table 2: *Alternative conceptions and their percentages for SSS 3*

| Question NO | Alternative Conceptions | Frequency | % |
|---|---|---|---|
| 1 | Chemical composition of DNA is nucleotide which is made of organic compound | 79 | 28.1 |
| 4 | Zygote is formed by fertilization process because it involves sexual intercourse | 96 | 34.2 |
| 6 | Sex is determined by dominant sex chromosome X and Y | 110 | 39.1 |
| 9 | Different cells (muscle cells, nerve cells, skin cell) function differently because they are located in different areas of the body | 99 | 35.2 |
| 12 | Gene is a part of chromosome | 75 | 26.7 |

Table 3 shows the distribution of male and female SSS 3 students' alternative conceptions of genetics. The Table shows that male and female SSS3 students offering biology possess alternative conceptions about genetics. Question 6 which asked about sex chromosome has the highest percentage of alternative conceptions with total number of 66 (41.3%) for male and 44 (36.4%) for female while question 14 that asked about variation has the lowest percentage of alternative conceptions with 12 (7.5%) male and 10 (8.3) female. Equal number of male 48 (30.0%) and female 48 (39.7%) has alternative conception in question 4 that asked about zygote formation.

Table 3
*Identified alternative conceptions on genetics*

| Concepts | Alternative Conceptions | Male Students | | | | Female Students | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Two-tier | | Three-tier | | Two-tier | | Three-tier | |
| | | Freq | % | Freq | % | Freq | % | Freq | % |
| DNA | Chemical composition of DNA is nucleotide which is made of organic compound | 50 | 31.3 | 46 | 28.7 | 39 | 32.2 | 33 | 27.3 |
| Homo zygote | Homozygote genes are from the same individual | 13 | 8.1 | 13 | 8.1 | 15 | 12.4 | 11 | 9.1 |
| Allele | Dominant allele makes heterozygote individual look like homozygote individual | 22 | 13.8 | 22 | 13.8 | 25 | 20.7 | 24 | 19.8 |
| Zygote | Zygote is formed by fertilization process because it involves sexual intercourse | 54 | 33.8 | 48 | 30.0 | 52 | 43.0 | 48 | 39.7 |
| Cell division | Cell division in skin cells result into the same genetic information in mother and daughter because cell content divides into equal half | 19 | 11.3 | 14 | 8.8 | 14 | 11.6 | 11 | 9.1 |
| Sex | Sex is determined by dominant sex chromosome X and Y | 78 | 48.8 | 66 | 41.3 | 55 | 36.4 | 44 | 45.5 |
| Pheno type | Phenotype is individual's appearance | 17 | 10.6 | 17 | 10.6 | 17 | 14.0 | 16 | 10.0 |
| | Gene functions as individual traits | 25 | 15.6 | 19 | 11.9 | 22 | 18.2 | 21 | 17.4 |
| Gene | Gene is a part of chromosome | 38 | 23.8 | 38 | 25.6 | 37 | 30.6 | 37 | 28.1 |
| Cell | Different cells (muscle cells, nerve cells, skin cell) function differently because they are located in different areas of the body | 64 | 40.0 | 52 | 32.5 | 57 | 47.1 | 47 | 38.8 |
| Mutation | Mutation destroys DNA structure | 29 | 18.1 | 14 | 8.8 | 9 | 7.4 | 6 | 5.0 |
| | Mutation produces new genetic materials | 16 | 10.0 | 11 | 6.9 | 25 | 20.7 | 20 | 16,5 |
| Geno type | Genotype is the behavior appearance of individual | 20 | 12.5 | 13 | 8.1 | 18 | 14.9 | 16 | 13.2 |
| Variation | Variation are the identifiable differences with population | 13 | 8.1 | 12 | 7.5 | 11 | 9.1 | 10 | 8.3 |

Table 4 shows that there was no significant difference in the number of alternative conceptions held by male and female senior school students offering biology since [$x^2_{(2,\ 281)}$ =1.17, p=24.99]. The p-value (32.67) is greater than 0.05 (level of significance) the null hypothesis was not rejected. It implies that gender has no influence on the number of alternative conceptions of genetics held by SSS 3 students.

Table 4: *Chi-square Analysis of Different in the Number of Alternative Conceptions Held by Male and Female SSS 3 Students Offering Biology*

| Group | Observed | Expected | N | Df | Cal. Value | Table Value | Sig. | Remark |
|---|---|---|---|---|---|---|---|---|
| Male | 385 | 364.5 | 160 | 280 | 1.17 | 32.67 | NS | Not rejected |
| Female | 344 | 364.5 | 121 | | | | | |

## 5. Major Finding

Three-tier diagnostic test accurately assess students' alternative conceptions of genetics Students' gender had no significant influence on the number of alternative conceptions held by SSS 3 students' offering biology [$x^2_{(2,\ 281)}$ =1.17, p=32.67].

## 6. Discussion and Conclusion

The result shows that many of the students who claim to understand genetics have wrong understanding referred to as alternative conception in this study. This is in accordance with Lewis and Wood-Robinson (2000) report that students of all ages often have considerable alternative ideas about genetic, some students believed that chromosomes and genetic information are shared but not copied during cell division, and that all chromosomes are either male (Y) or female (X).

Students' gender had no significant influence on the number of alternative conceptions held by SSS 3 students' offering. This is in agreement with the findings of Ekong, Akpan, Anongo and Okrikata (2015) study on influence of selected variables on students' academic performance in genetics and their applications for effective application of stem education that the t-test analysis revealed a non-significant difference for students' gender. Although Jone, Howe and Rua (2000) reported that significantly more females than males see science as a difficult subject to understand, in this study, both groups still have wrong understanding about genetic concepts.

All the findings obtained indicate that the three-tier diagnostic test can be used to evaluate students' conceptions effectively and accurately. As it is shown in Table 2, genetic concepts in which students have strong alternative conceptions about are DNA, Zygote Formation, Cell Function, Sex and Gene. It is obvious that these alternative conceptions cannot be prevented by traditional teaching methods, since in this study it is found that the students solidify their alternative conceptions. After the alternative conceptions have been identified, they may be removed with proper methods described in the literature Salih, Erol & Sacit (2004).

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