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Analysis of diagram errors in selected Nigerian secondary school practical biology textbooks

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ABSTRACT

Evidence abounds in science education literature that science textbooks are not always error-free and that inaccuracy in diagrams creates confusion, misconceptions, and hinders meaningful learning. Therefore, in this textbook research study, an attempt was made to identify, analyze, and classify diagram errors in four selected Nigerian biology practical textbooks. The purposive sampling technique was used to select four widely used practical biology textbooks. Two instruments designed by the researchers namely, Compendium of Practical Biology Textbooks (CPBT) and Diagram Error Identification Proforma (DEIP) were used for data collection. Each diagram in the four selected textbooks was carefully analyzed for the identification of errors. The identified errors were analyzed, classified, coded, and subjected to statistical analysis. Results indicated that diagrams in the four textbooks were rife with spelling, labeling, and technical errors and that there was a significant difference between the numbers of diagram errors in the four selected textbooks in favor of Textbook C (X2 =59 DF 24, P=0.00). It was concluded that the selected Nigerian practical biology textbooks were laden with various types of diagram errors that could impact students' performance negatively. Urgent revision of the textbooks was recommended to stem the negative impacts of the diagram errors on students' performance.

Introduction

Diagram plays a crucial role in biological reasoning; it represents how parts of a specimen relate to each other, and it is an age-long tradition; consequently, biology textbooks written for teachers and students are rich in diagrams. The study of organisms demands meticulous scientific observations and detailed descriptions of specimens; hence, diagrams as an excellent way to describe observations are indispensable in biology (Anta, 2019; Bhatti et al., 2015; Jones & Wolkenhauer, 2012). According to Sheredos et al. (2013), diagrams are suitable tools for exhibiting biological phenomena and revising mechanistic explanations of the phenomena. Indeed, teaching and learning biology without diagrams as visual representations is inconceivable.

Visual representations are potent tools for making 'unseen seen and the complex simple' as noted by Quillin and Thomas (2015). Qasim and Pandey (2017), observed that biological conceptual learning requires visualization and diagrams are potent conveyors of abstract and concrete information. Komalasari et al. (2019) noted that the application of diagram convention in learning enhances students' understanding of biological concepts. There are indications that diagram errors impacted negatively on the performances of Nigerian secondary school students at the West African Senior School Certificate Examinations (WASSCE) as reflected in the Chief Examiner's Annual Reports for 2015,2016, 2017, 2018, and 2019 (West African Examinations, 2021). The annual reports observed many types of diagram errors in candidates' answer scripts. The diagram errors include: (1). Wrong spelling of labels and technical terms; (2). Drawing of poor diagrams with loss of details; (3). Production of diagrams with woolly and broken lines, freehand guidelines, and non-horizontal labels; (4). Not giving titles or magnifications for diagrams and not conforming to size specifications; and (5). Not drawing guidelines to touch the label on the diagram, among others. The repetitive nature of the errors over many years certainly calls for an investigation.

Textbooks are indispensable curricular resources especially in developing nations like Nigeria where most students have limited access to other learning resources. Students and Teachers often depend on textbooks as a reliable source of knowledge and skills as noted by Hanks (2013); Novitasari et al. (2019); Oxford University Press (2011); and Teachers Vision (n.d.). This perhaps partially accounts for several studies in the field of science education on textbook analysis. Indeed, Vojíř and Rusek (2019) noted that publications on textbook analysis are increasing, and that researchers in Europe and the USA carried out more works on textbook analysis than researchers from other regions of the world and that secondary school science textbooks were the most research on. Previous studies on biology textbook analysis such as (Bhatti et al., 2015; Candra et al., 2020; Catley & Novick, 2008; Çobanoğlu & Şahin, 2009; Dao, 2012; Dikmenli, 2015; Lestari & Zulyusri, 2021; Nair, 2019; Novitasari et al., 2019; Pednekar, 2013; Raharjo et al., 2018; Ramnarain & Padayachee, 2015; Sunarmi & Sari, 2020) revealed that biology textbooks are often laden with diagram errors, misconceptions, inaccurate content presentation, curricular issues, and other forms of inaccuracies. Errors in a biological diagram could significantly hinder biological conceptual learning through visualization. Literature evidence indicated that not many studies ventured into an analysis of diagram errors in biology textbooks.

Therefore, four research questions were raised in the study: (1) Are there diagram errors in the selected practical biology textbooks? (2) What are the categories of diagram error in the selected practical biology textbooks? (3) What is the most and the least common types of diagram error in the selected practical biology textbooks? (4) Is there a significant difference among the numbers of diagram errors in the selected biology textbook?

Method

Textbook research method was adopted in this study. The study focused on factual accuracy, specifically qualitative and quantitative approaches were used for the analyses of the identified diagram errors in the selected books. Four Nigerian practical biology textbooks were selected and analyzed in the study. Two research instruments namely (i) Compendium of Practical Biology Textbook (CPBT) and (ii) Diagram Error Observation Proforma (DEIP) were developed to gather data in the study. The content and face validity of the two instruments were established by one experienced senior secondary school biology teacher; one Senior Lecturer in the field of biology education from a university; and one experienced WAEC Biology Examiner. The CPBT was designed to generate a list of Nigerian practical biology textbooks, while DEIP was an observation instrument designed to record observed diagram errors in the selected practical biology textbooks. The CPBT was administered to 104 biology teachers and 241 students across two states in Nigeria.

The purposeful sampling technique was then used to select the four most frequently listed practical biology textbooks out of the 16 practical biology textbooks generated from the field survey. The selected practical biology textbooks

were: (i) Olaniyonu, B. A. (2004). Essential practical biology. Lagos: Tonad Publishers (Textbook A) (Olaniyonu, 2004); (ii) Ogundana,S. K. (1994). A guide to practical biology for senior secondary school. Ibadan: Evans Brothers (Textbook B) (Ogundana, 1994); (iii) Iloeje, S. O. (1991). Senior school certificate practical biology. Lagos: Learn Africa (Textbook C) (Iloeje, 1991) and Duyilemi, B. O. and Duyilemi, A. N. (2000). Practical biology for schools and colleges. Ibadan: Gbabeks (Textbook D) (Duyilemi & Duyilemi, 2000). The researchers developed a coding system from existing literature. The coding system was based on the basic quality, principles, and techniques of a biological diagram. The codes were; (a) AHGL-Arrowhead Guideline (b) DWL- Diagram without Label (c) GNTSD-Guidelines not Touching the Structure on the Diagram, (d) NHGL-Non-Horizontal Guidelines, (e) NLIP-Not Labeling Important Part, (f) WSLS-Wrong Spelling of Labeled Structure, (g) UPLSS-Use of Plural Word to Label a Single Structure, (i) USWLMS-Use of Singular Word to Label Multiple Structures, and (j) WLS-Wrongly Labeled Structure.

Each diagram in the selected practical biology textbooks was carefully studied and observed errors were recorded on DEIP. The four practical biology textbooks and the observed diagram errors recorded in DEIP were submitted to a three-member panel for validation. The panel consisted of an experienced WAEC biology Examiner, a Senior Lecturer in the field of Biology Education, and another in the field of Biology. Their comments were used to revise the data collected before quantitative analysis was carried out using percentage and chi-square statistical tools. The quantitative analysis was done in six stages as follows: (1) The number of each type of error in each textbook was calculated (2) The total number of all types errors in each textbook was sum-up to ascertain the total number of errors identified in each textbook. (3) The percentage of each type of error in each textbook was then calculated (4) The total number of errors in each textbook was added up to ascertain the total number of errors in all the four textbooks. (5) The percentage of each type of error in all the four textbooks was calculated. (6) Chi-square statistical tool was used to test for statistically significant difference among the number of diagram errors in the four textbooks.

Results and Discussion

The four selected practical biology textbooks contain diagram errors. Nine types of diagram errors were identified based on the adapted coding. The nine types of diagram errors were categorized into three viz; (a) Labeling Errors, (b) Spelling Errors, and (c) Technical Errors. Quantitative analysis of the data gathered in the study was carried out using percentage and chi-square statistical tools. The results of the analyses were presented in Tables 1, 2, and 3.

Research Question 1: Are there diagram errors in the selected practical biology textbooks?

Diagram errors were identified in all the four selected practical biology textbooks. Table 1 showed that out of the 232 diagrams in Textbook A, 75 (32.32%) contain errors. The percentage of each type of diagram error identified in the textbook were as follows; DWL (8.18%), WSLS (3.44%), GNTSD (4.31%), NHGL (9.91%), UPLSS (4.74%), USWLMS (1.29%) and AHGL (0.43%). The most common error in the textbook was NHGL while the least common was AHGL. There were 235 diagrams in Textbook B and 60 (25.53.78%) contained errors. The various types of error identified in the textbook were as follow; DWL (9.78%), GNTSD (0.85%), NHGL (8.93%), NLIP (0.42%), UPLSS (4.68%), USWLMS (0.42%) and WLS (0.42%). The most prevalent type of error in Textbook B was DWL while the least was NIIP.

There were 325 diagrams in Textbook C, out of which 60 (18.46%) contained errors. The most common error in the textbook was DWL (6.46%) while the least common was AHGL (0.30%). Other types of errors identified in the textbook were AHGL (0.30%), WSLS, (0.61%), GNTSD (0.92%), NHGL (0.92%), UPLSS (5.84%) and USWLMS (3.07%). Textbook D contained 241 diagrams, only 75 (31.12%) of the diagrams had errors as shown in Table 1. The types of diagram errors identified in the textbook were; DWL (4.98%), WSLS (1.18%), GNTSD (2.13%), NHGL (6.17%), UPLSS (1.42%), USWLMS (1.42%), and WLS (0.47%). Obviously, from the foregoing NHGL was the most common diagram error while WLS was the least common error in the textbook.

Visual and textual information in biology textbooks is expected to play a complementary role in conceptual

learning. Errors in visual information contained in biological diagrams amounted to a disparity in visual and text information, the consequence of which is difficulties in conceptual processes. Hence, the aforementioned findings in this study implied that students and teachers using the textbooks most likely have been encountering difficulties in biological conceptual learning through visual representation of biological structures and concepts in the diagrams. Wrongly labeled structures and wrong spellings in the diagram could predispose students to construct misconceptions of the concepts and structures depicted in biological diagrams. Indeed, any form of distortion of visual representation of biological structures could inhibit; the development of model-based reasoning in biology, accurate visualization, and by extension appropriate conceptualization of biology structures, phenomena, and concepts by the students. The findings are consistent with that of Pednekar (2013) and Catley and Novick (2008) that equally reported various types of diagram errors in biology textbooks. The findings tend to provide a plausible reason for the diagram errors observed in candidates' answer scripts reported by the West African Examinations Council Chief Examiner's Reports (West African Examinations, 2021) because students often rely on textbooks as reliable learning material. Diagram errors identified in this study suggested that the authors of the selected practical biology textbook paid little attention to basic qualities and other requirements in a visual representation of biological structures. The finding equally suggested that most likely the practical biology textbooks were not subjected to rigorous blind peer review exercise before publication; otherwise, most of the diagram errors would have been identified and corrected by peer reviewers. Findings of this study were partially consistent with the results of earlier studies on biology textbook analysis which revealed that biology textbooks are often laden with inaccuracies such as misconceptions, content presentation, and curricular issues among others (Bhatti et al., 2015; Çobanoğlu & Şahin, 2009; Dikmenli, 2015; Lestari & Zulyusri, 2021; Novitasari et al., 2019; Raharjo et al., 2018; Ramnarain & Padayachee, 2015).

Research Question 2: What are the categories of diagram error in the selected practical biology textbooks?

Three categories of diagram error were identified in the four selected practical biology textbooks namely, Labeling Error, Spelling Error, and Technical Error as presented in Table 2. Labeling Error category includes; not labeling important parts (NLIP), wrongly labeled structure (WLS), and diagram without a label (DWL). The Spelling Error category consisted of wrong spelling of labeled structure (WSLS), use of the singular word to label multiple structures, (USWLMS), and use of the plural word to label a single structure (UPLSS).

Table 1. Examples, number and percentages of diagram errors identified in the selected Nigerian practical biology textbooks

Textbooks	A		B		C		D	
Errors	Example	No/%	Example	No/%	Example	No/%	Example	No/%
AHGL	Fig.1.1	1(0.4%)	Nil	0(0%)	Fig.1.1	1(0.3%)	Nil	0(0%)
DWL	Fig.6.7	19 (8.1%)	Fig.8.2	23(9.7%)	Fig.1.3	21(6.4%)	Fig.1.10	21(4.9%)
WSLS	Fig.2.4	8 (3.4%)	Nil	0(0%)	Fig.9.25	2(0.6%)	Fig.17.6	5(1.1%)
GNTSD	Fig.4.2	10 (4. 3%)	Fig.4.11	2(0.8%)	Fig.17.26a	3(0.9%)	Fig.14.1	9(2.1%)
NHGL	Fig.8.7	23 (9.9%)	Fig.15.7	21(8.9%)	Fig.19.2a	3(0.9%)	Fig.16.5	26(6.2%)
UPLSS	Fig.3.7	11 (4.7%)	Fig.5.7	11(4.6%)	Fig.16.1	19(5.8%)	Fig.4.17b	6(1.4%)
USWLMS	Fig.3.4	3(1.2%	Fig.5.6	1(0.42%)	Fig.17.3	10(3.1%)	Fig.17.2	6(1.4%)
WLS	Nil	0(0%)	Fig.1.3	1(0.42%)	Fig.4.2d	1(0.30%)	Fig.2.5	2(0.47%)
NLIP	Nil	0(0%)	Fig.11.1	1(0.4%)	Nil	0(0%)	Nil	0(0%)
Percentage of Diagrams with Error	75/232 (32.32%)		60/235 (25.53%)		60/325 (18.46%)		75/241 (31.12%)	

Table 2. Categories of diagram errors identified in selected Nigerian practical biology textbooks

Labeling	Number (%)	Spelling	Number (%)	Technical	Number (%)
NLIP	1(0.40%)	WSLS	15(6.09%)	AHGL	2(0.81%)
WLS	4(1.62%)	USWLMS	20(8.13%)	GNTSD	24(9.75%)
DWL	84(34.14%)	UPLSS	47(19.10%)	NHGL	73(29.67%)
Subtotal	**89(36.17%)**		**82(33.33%)**		**99(40.24%)**
Grand Total				**246/1033=23.81%**	

Table 3. Chi-Square test of significant difference among the numbers diagram errors in the selected practical biology textbooks

Textbooks	Diagram Errors								
	AHGL	DWL	PSLTT	GNTLD	NHGL	UPLSS	USLMS	WLS	NLIP
A	0(0.56)	21(23.3)	5(4.17)	9(6.67)	26(20.3)	6(13.1)	6(5.56)	2(1.11)	0(0.28
B	1(0.44)	21(18.7)	2(3.33)	3(5.33)	3(16.2)	19(10.4)	10(4.44)	1(0.89)	0(0.22)
C	0(0.44)	23(18.7)	0(3.33)	2(5.33)	21(16.2)	11(10.4)	1(4.44)	1(0.89)	1(0.22)
D	1(0.56)	19(23.3)	8(4.17)	10(6.67)	23(20.3)	11(13.1)	3(5.56)	0(1.11)	0(0.22)

X^2 =59 DF 24, P=0.00

The Technical Error category consisted of; non-horizontal guidelines, (NHGL) use of arrowhead guideline (AHGL), and not drawing guidelines to touch the structure on the diagram (GNTSD). Technical errors accounted for 40.24% followed by labeling errors (36.17%) and spelling errors (33. 33%). This finding indicated that the authors of the selected textbooks were most likely not conversant with the technicalities involved in drawing a biological diagram. It equally suggested that the authors did not thoroughly proofread the manuscripts to detect labeling and spelling errors. Labeling errors such as WLS could result in re-enforcement of existing misconceptions or the formation of new misconceptions in the students' cognitive structures. A technical error such as GNTSD could distort students' visual perception ability. While spelling errors could render information in biological diagrams useless pedagogically. In the light of the forgoing biology textbook, authors should always endeavor to subject the manuscripts of their textbooks to rigorous proofing reading exercises to enhanced accuracy.

Research Question 3: What is the most and the least common type of diagram errors in the selected practical biology textbooks?

The most common diagram error was DWL, which accounted for one in every three diagrams (34.14%) in the four selected practical biology textbooks. The least common diagram error was NLIP, which accounted for just (0.40%) of the 246 diagram errors in all the selected practical biology textbooks as indicated in Table 2. This result tends to suggest that the authors of the selected practical biology textbooks were oblivious of the fact that diagrams without labels cannot convey any biological information in a clear manner hence, are of little or no pedagogical value. Diagrams without a label are akin to visual arts created for a non-scientific purpose.

Research Hypothesis: H_{01} Significant difference does not exist among the numbers of diagram errors in the selected practical biology textbooks.

The chi-square statistical technique was used to test the hypothesis and the result was presented in Table 3. The chi-square value (X^2 =59 DF 24, P= 0.00<0.05) was found not to be significant hence, the hypothesis was rejected. This result indicated that there was a significant difference among the numbers of each type of diagram errors in the selected practical biology textbooks in favor of Textbook C with the least percentage of errors per book. This was an indication that the author of Textbook C exhibited a higher level of precautionary measures to avoid diagram errors than the others. The author of Textbook A with the highest percentage of diagram error per book exhibited an unsatisfactory disposition toward ensuring the accuracy of the diagrams in the textbook. Students often do not question the reliability and accuracy of the contents of textbooks that they are using. It is thus, obvious that diagram errors in the selected practical biology textbooks would have been assimilated as the appropriate visual representation of biology structures, concepts, and phenomena depicted in the diagrams.

In the light of these findings, the authors of the selected Nigerian practical biology textbooks must subject the books to revision exercise and ensure that all

biological diagrams are free from spelling, labeling, and technical errors. Doing this will stem the negative impacts of the diagram errors in the textbooks on students' biological conceptual learning through visual representation. In addition, biology textbook authors should endeavor to embrace the practice of subjecting their works to rigorous peer review exercise before publication. This will help to improve the accuracy of the diagrams among other contents of biology textbooks. Furthermore, it is incumbent on the authors of practical biology textbooks to include the basic technical guidelines for drawing biological structures in their textbooks. This will assist the students to identify and avoid diagram errors and thereby improve their performance in biology. More importantly, Biology teachers should always evaluate the accuracy of the diagrams in practical biology textbooks before recommending the books to students while students and teachers should not take the accuracy of diagrams in biology textbooks for granted.

Conclusion

The researchers concluded that there were many diagram errors in all the selected Nigerian practical biology textbooks which include; spelling, labeling, and technical errors of various types that could impact students' meaningful learning negatively. It was also, concluded that Diagrams without Labels and Not Labeling Important Parts were the most and least types of errors respectively, while there was a significant difference in the numbers of diagram errors in the selected textbooks. This study has contributed to the existing stock of knowledge on the accuracy of contents of biology textbooks by uncovering the existence of spelling, labeling, and technical diagram errors in practical biology textbooks. It has provided empirical evidence that the accuracy of diagrams in biology textbooks should never be taken for granted by students and teachers among other users.

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Appendix:1
Sample of Each Types of Error Identified in the Selected Biology Practical

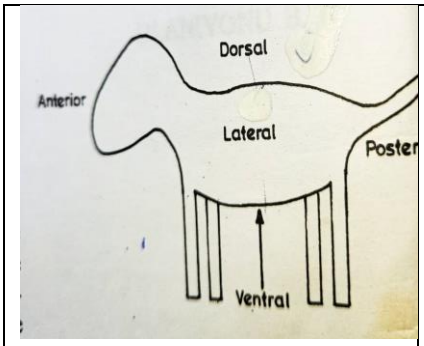

Figure 1: AHGL

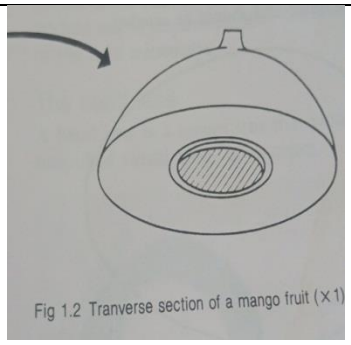

Figure 2: DWL

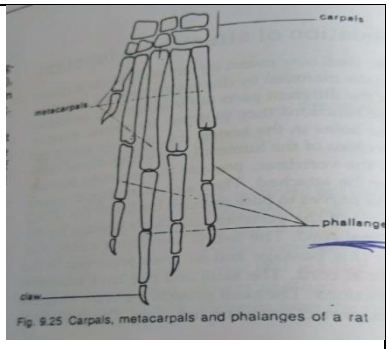

Figure 3: WSLS

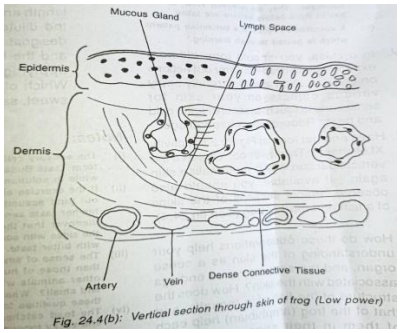

Figure 4: NHGL

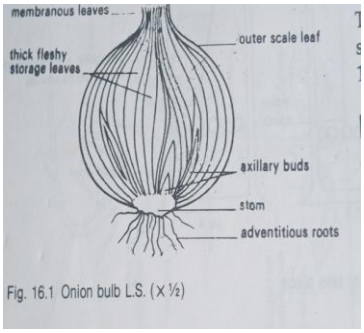

Figure 5: UPLSS

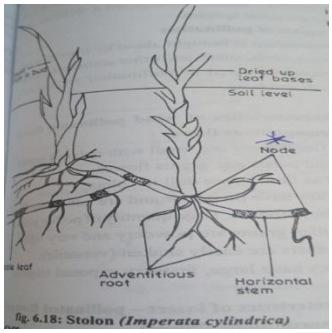

Figure 6: USWLMS

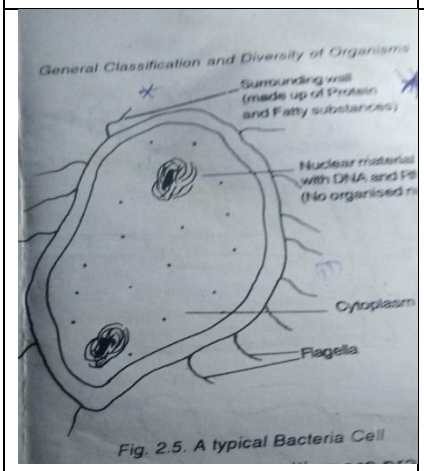

Figure 7: WLS

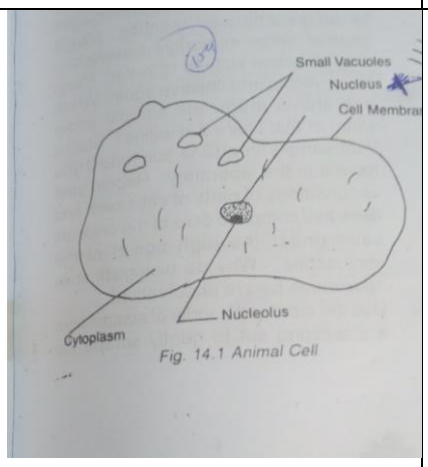

Figure 8: GNTSD

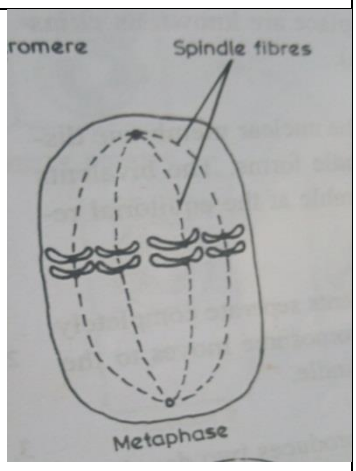

Figure 9: NLIP

Textbooks
AHGL–Arrowhead Guideline
DWL–Diagram without Label
GNTSD–Guidelines not Touching the Structure on the Diagram
NHGL–Non-Horizontal Guidelines,
NLIP–Not Labeling Important Part,
WSLS–Wrong Spelling of Labeled Structure,
UPLSS–Use of Plural Word to Label a Single Structure,
USWLMS–Use of Singular Word to Label Multiple Structures,
WLS–Wrongly Labeled Structure.