EFFECTS OF INQUIRY METHOD INCORPORATING REFUTATIONAL TEXT ON SECONDARY SCHOOL STUDENTS' UNDERSTANDING OF THE CONCEPT OF PHOTOSYNTHESIS AND RESPIRATION IN PLANTS.

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Abstract

It has been observed that senior secondary school students have several misconceptions of the concept of photosynthesis and respiration in plants arising from textbooks and teaching method used in teaching biology in secondary schools in Edo State. These two issues have led to the poor conceptual understanding and performances in examinations witnessed in the subject over the years. This study therefore examined the effects of inquiry method incorporating refutational text as a teaching strategy for improving conceptual understanding of the concept of photosynthesis and respiration in plants. The non-randomized pretest, posttest quasi-experimental design was employed and the simple random sampling technique was used to select 129 students who participated in this study. A two tier diagnostic instrument for assessing students' achievement and conceptual understanding and an Instructional Package was employed for the study. The treatments were randomly assigned to students in their intact classes made up of two experimental groups and a control group for a period of 10 contacts. The reliability of the instrument was established through the Kuder-Richardson formula 20 and a coefficient value of 0.70 was obtained. Data were collected and analysed using ANOVA and ANCOVA. ANCOVA was employed to compare post-test conceptual understanding scores of experimental and control groups using the pretest scores as covariate and the posttest as criterion. Findings revealed that students taught using inquiry method incorporating refutational text significantly restructured their understanding of the concept better than those in the control group who made use of the traditional instructional method. There was no significant difference in conceptual understanding of the concept between males and females in the experimental groups. It was therefore recommended that, all the stakeholders in education must seek to identify the misconceptions that students have in a given

science concept and develop instructional texts such as the refutational texts that can address and improve conceptual understanding.

Keywords: Inquiry Method, Refutational Text and Conceptual Understanding.

Introduction

Biology can be defined as the study of living things. Its objectives include acquisition of necessary scientific skills for classifying and interpreting biological data. The knowledge acquired from its study is needed for future advancement in the biological sciences, such as in the study of Medicine, Pharmacy, Nursing, Brewing, Microbiology and other related disciplines. To achieve this advancement, students need to have the correct understanding of all the concepts in biology. Therefore, a poor foundation in biology at the secondary school level will jeopardize any future effort to enhance scientific and technological development. Omoifo (2012) noted that over the years, students' performances in biology and other science subjects have been poor. These poor performances could be a proof that both teachers and students have difficulties in teaching and learning the concepts in Biology respectively. The lack of the needed resources makes teachers rely solely on the use of chalk and talk. This further explains the dependence of teachers on science textbooks and lecture method as the major instructional strategies.

Anjum (2008) noted that textbooks are one of the causes of misconceptions and such were also identified in five ordinary level expository texts in biology used in Nigeria and elsewhere. This has further been verified by several researchers who have compiled over 20 misconceptions which exist in the concept of photosynthesis and respiration in plants in Biology. Examples of such misconceptions are; respiration as synonymous with breathing, plants do not respire, plants get their food from the soil and photosynthesis is the respiration of plants in light and so on. Due to these identified misconceptions which exist in several scientific concepts, many studies on conceptual change suggested that these misconceptions impede students' understanding. This gave rise to the focus on conceptual change theory in which old information is replaced by the new one for meaningful learning to occur, it also gave rise to Posner, Strike, Hewson & Gertzog's (1982) four conditions for clearing misconceptions i.e. dissatisfaction, intelligible, plausible and fruitful view. Thus the process of conceptual change is likely to begin when the scientific view point is presented which in turn will trigger cognitive conflict within the individual who holds misconception in the particular concept of study.

A number of studies have investigated the use of several instructional strategies that promote conceptual change. Such strategies include the cognitive conflict approach, concept mapping, analogies, concept cartoons, discussion, demonstration, narrative texts, conceptual change texts, refutational texts among

others. These strategies have been found to be very effective in clearing misconceptions and improving learning. Amongst these strategies, the refutational texts have been found to be very effective because they promote high cognitive engagement conflict. Refutational text is a conceptual change strategy employed for teaching and clearing misconceptions. Specifically, 'a refutation text is an expository text that acknowledges the misconceptions a reader may hold about a topic, explicitly refutes them, and presents the scientific explanations as viable alternatives' (Tippett, 2010). In particular, three structural components of a refutation text have been defined; (1) The statement of the misconceptions a reader may hold about the topic presented in the text, (2) a signal or cue that alerts the reader to the possibility of another explanation, followed by (3) the statement of the currently accepted scientific explanation. As defined, the first two components could be properly referred to as the "refutation statement". In contrast, a standard or traditional text (non-refutational text) only provides the new scientific information. A traditional form of learning science is through reading textbooks that expose student to new and unfamiliar scientific facts. Researchers have claimed that non-refutational texts typically do not invite students to critically think about the facts or concepts being presented and reconcile such facts to their prior knowledge and misconceptions (Braten, Britt, Strømsø, & Rouet, 2011). This problem may be amplified when students are learning science topics with contradictory or divergent viewpoints. Indeed, non-refutational science texts are replete with expository presentations of facts that may not trigger the cognitive conflicts needed to initiate conceptual change in the learner. As it appears evident, the main difference between a refutational and non-refutation text is that, in the refutational text the readers' misconceptions concerning the concepts of interest are signaled by refutational statements, whereas in the non-refutational texts, they are not. As an instructional strategy, refutational text is therefore compatible with a constructivist view of learning because it recognizes that students have prior conceptions, some of which may be at variance with the scientific viewpoint.

In some studies, refutational texts have been combined with other instructional method such as discussion method, interactive discussion method and narrative methods. The importance of the explanation component in refutational texts has been established in a series of experiments in which (Kendeou, Walsh, Smith, and O'Brien 2014), they examined the effect of each of the components of refutational texts by comparing refutation-plus-explanation, refutation-only, and explanation-only versions of texts. However, one line of research that has not been fully explored is the use of refutational text combined with inquiry method of instruction. Inquiry can be defined as a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena. In an inquiry setting, students acquire knowledge and develop a rich understanding of concepts, principles, models and theories. The term 'inquiry' also generally

signifies finding truth or knowledge that requires thinking critically, making observations, asking questions, performing experiments, stating conclusions, thinking creatively and using intuition. This way, students then learn science in a way that reflects how science actually works unlike the lecture method which remains one of the popular methods of teaching biology in Nigerian secondary schools. Most teachers of Biology widely adopt lecture method because it provides for an effective use of time and manpower. It enables teachers to present many ideas to a large group in a relatively short period of time. However, Bimbola and Daniel (2010), noted that lecture method makes learners passive in the teaching/learning process.

Therefore, this study examined the effects of inquiry method with refutational text on secondary school student's conceptual understanding of photosynthesis and respiration in plants. It will also investigate the differential effectiveness of using inquiry instructional method incorporating refutational text on students' conceptual understanding between male and female students in the concept of photosynthesis and respiration in plants.

Statement of the Problem

Within the last three decades, the interest of researchers appears to have turned to the topic of students' misconceptions in the area of science. It is one of the most important factors which prevent students' meaningful and permanent learning especially in science. Misconceptions are what students themselves develop erroneously and different from scientifically accepted concept. The traditional Biology textbooks (non-refutational text) have been identified as one of the major sources of misconceptions. The use of such non-refutational texts as an instructional tool for teaching have several negative consequences as noted by (Tippett 2010). Other researchers have claimed that such expository approaches to science learning, although widespread and normative, may not be as effective as other strategies because they may be difficult to comprehend. Learners may not use effective reading strategies to understand the text and hence their misconceptions may not be directly challenged (Sinatra & Broughton, 2011& Snow, 2002).

To overcome this problem, researchers have developed different text structures such concept maps, use of analogies, 5E, conceptual change texts and refutational texts. The refutational texts have been reported to be very effective in creating conceptual change, improving academic performances and promoting meaningful understanding in students.

The question is, will the use of inquiry method incorporating refutational text create conceptual understanding of photosynthesis and respiration in plants in secondary school students? Will the use of inquiry method incorporating refutational text be an effective instructional strategy for eliminating misconceptions in photosynthesis and respiration in plants? Will inquiry method incorporating refutational text be

more effective than the lecture method incorporating non-refuational text in the teaching of photosynthesis and respiration in plants? Will there be any difference in conceptual understanding between the male and female students taught with the instructional packages in the concept of photosynthesis and respiration in plants?

Research Questions

The following research questions were raised:

1. What percentage of senior secondary school biology students have correct conceptions of photosynthesis and respiration in plants at pretest?
2. Is there any difference in the conceptual understanding between students taught using inquiry method with refutational text, inquiry method with non-refutational text and lecture method with non refutational text in photosynthesis and respiration in plants?
3. Is there gender difference in the conceptual understanding of students taught using inquiry method with refutational text, inquiry method with non-refutational text and lecture method with non refutational text in photosynthesis and respiration in plants?

Hypotheses

Research question one was answered while research questions two and three were hypothesized and tested at 0.05 level of significance.

1. There is no significant difference in the conceptual understanding between students taught using inquiry method with refutational text, inquiry method with non-refutational text and lecture method with non refutational text in photosynthesis and respiration.
2. There will be no significant gender difference in the conceptual understanding of students taught using inquiry method with refutational text, inquiry method with non-refutational text and lecture method with non refutational text in photosynthesis and respiration in plants.

Methods

The pre-test post-test non-randomized quasi-experimental design where intact classes were used was employed for this study. The population of the study was made up of 1355 S. S. 2 students from of all the five (5) Co-educational Government Senior Secondary Schools in Oredo Local Government Area of Edo State, Benin City. The simple random sampling technique was used to select the sample size of one hundred and twenty-nine (129) students from three (3) Co-educational Government Senior Secondary Schools out of the five.

Data was collected using two instruments, Test of Conceptual Understanding on Photosynthesis and Respiration in Plants (TCUPR) and an Instructional Package made up of three texts designed for the three groups. The (TCUPR) is a two-tier

diagnostics instrument made up of sections A and B. Section A contains information on students' bio-data which indicates their gender (male or female), while section B consists of fifteen (15) test items two-tier diagnostic instrument. The test is a combination of a multiple choice question with reasons, adopted from "What do You Know About Photosynthesis and Respiration in Plants?" developed by Haslam and Treagust (1986) and previously standardized West Africa Examination Council (WAEC) examination questions. Each question in section B has two parts – Part I is an objective question with four options A, B, C and D. While Part II consists of four (4) reasons to the correct option in Part I. In both parts, a correct option and reason is included. A student is considered to have the correct conception when the right option and reason are ticked. A misconception is identified when the student picks the right option but the wrong reason. A student is said to have a correct conceptual understanding when they pick the correct answer and the correct reason for the answers from the options. These questions were carefully selected to identify right conceptions or misconceptions in limited but clearly defined content area using a table of specification for the validation of the instrument.

Instructional Package

The instructional package consists of three instructional strategies each containing a text which are; Inquiry Method and Refutational Text (IRET); Inquiry Method and Non-Refutational Text (INRET) and Lecture Method and Non-Refutational Text (LNRET).

Treatment Procedure

The three groups had 10 contacts in which the pretest was carried out on the first contact and posttest on the tenth contact. The Instructional Package was administered for eight contacts each to the three groups. The students in experimental group one made use of IRET, while the students in experimental group two used INRET and the students in the control group used LNRET.
The instructional plan for the three groups are presented in Table 1.

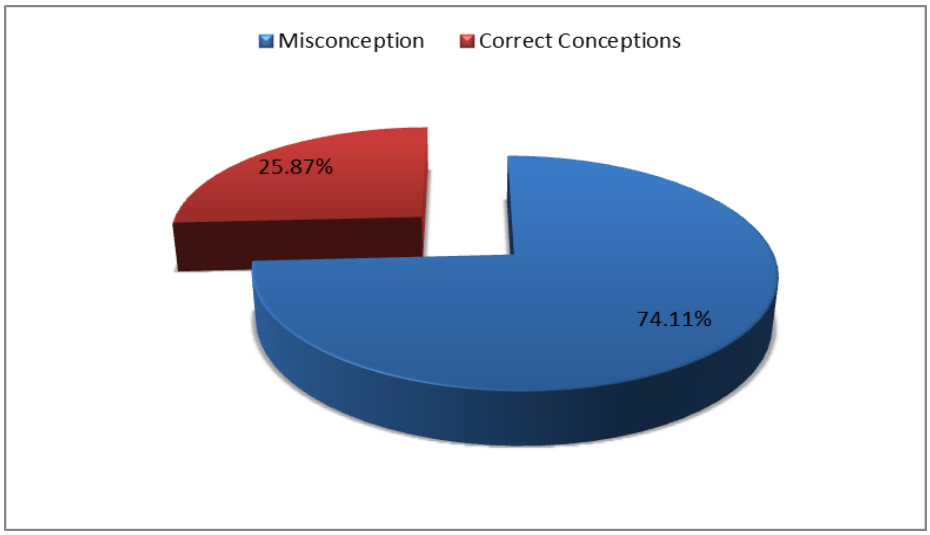
Table 1: Instructional Plan During the Treatment

Groups	Week 1(Contact one)	Week 2-6 (8 Contacts)	Week 7 (Contact ten)
EGI	Pre-test	Inquiry with RET	Post-test
EGII	Pre-test	Inquiry with NRET	Post-test
CG	Pre-test	Lecture with NRET	Post-test

Frequencies and percentages were used to determine misconceptions before and after treatment. Hypothesis one was tested using ANOVA and the mean scores of students in the different groups were compared using Oneway analysis of covariance (ANCOVA) for hypothesis two.

Results

Research Question One: What percentage of senior secondary school biology students have correct conceptions of photosynthesis and respiration in plants at pretest?



An average of 74.11percent of the students had misconceptions of the concept of photosynthesis and respiration in plants at pretest before the treatment as illustated in Figure 1.

Figure 1: Average Percentage of Students with Misconceptions and correct conceptions of Photosynthesis and Respiration in Plants at Pretest

Results from the chart show that a majority of the students, with an average of 74.11 percent had misconceptions in all the test items over and above an average 25.87% of students with correct conceptions of the concept of Photosynthesis and Respiration in plants before treatment.

It would be observed in table 2 that only in one item (item 15) did more than 50 percent of the students (58.1) have correct conception of photosyntesis and respiration in plants at pretest. In three of the items (8, 2 and 11), the percentage of students with correct conception of photosynthesis and respiration in plants ranged between 41.1 to 48.8 percent. Results show that in eleven of the fifteen items, less than 40 percent of the students had correct conceptions of photosythesis and respiration in plants. The results are summarized in Table 2.

Table 2: Percentage of Students with Correct Conceptions in Photosynthesis and Respiration in Plants

Test Items	% of correct conceptions
1. Gas is taken in by green plants.	3.9
2. Benefit of photosynthesis to green plants.	45.0
3. Photosynthesis is another form of Respiration.	20
4. What is plant's food?	13.8
5. Why do animals respire and plants photosynthesize?	6.9
6. When does respiration in plants only occur?	37.2
7. Where does respiration in plants take place?	41.1
8. What is the most important benefit of photosynthesis to plants?	24.0
9. Respiration in plants occurs when?	20.9
10. Do plants respire?	16.3
11. What is the purpose of respiration in plants?	48.8
12. Which of the following is plant's food?	37.2
13. Similar characteristics of photosynthesis and respiration	7.0
14. Plants cannot respire.	7.8
15. One similarity between photosynthesis and respiration in plant.	58.1

Hypothesis One:

There is no significant difference in the conceptual understanding of students taught using inquiry method with refutational text, inquiry method with non-refutational text and lecture method with non refutational text in photosynthesis and respiration in Plants.

Table 3 is a summary of the descriptive statistics showing students' post mean scores on conceptual understanding.

Table 3: Summary of Descriptive Statistics of Students' Post Mean Conceptual Understanding Scores by Group

Groups	N	Mean	Std. Deviation
Experimental Group 1 (IRET)	47	11.94	1.881
Experimental Group 2 (INRET)	60	8.75	2.440
Control Group (LNRET)	22	3.45	2.064
Total	129	9.01	3.633

Results from Table 3 showed differences in the post mean conceptual understanding scores for the three groups. Experimental group one had a mean score of 11.94 higher than 8.75 for experimental group two and the control group had a mean score of 3.45. To test for the significant difference between the three groups, analysis of variance (ANOVA) was employed (since there was no significant difference in the groups' mean conceptual understanding scores at pretest). The results are presented in Table 4.

Table 4: Summary One-way ANOVA Results on Students Post Conceptual Understanding scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1085.479	2	542.740	113.312	.000
Within Groups	603.513	126	4.790		
Total	1688.992	128			

*sig<0.05

The results as presented in Table 4 reveals F=113.312, df =2 and significant at 0.00. Since 0.00 is less than 0.05 level of significance, there is a statistically significant difference in the mean achievement scores of the three groups. The null hypothesis of no significant difference is therefore rejected. To further determine where the significance lies, a Scheffe's post-hoc analysis was carried out and the results are presented in Table 5.

Table 5: Scheffe's Post-Hoc Test on Mean Scores for Students Conceptual Understanding of Photosynthesis and Respiration in Plants by Treatment

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.
Experimental Group 2 (INRET)	Experimental Group 1 (IRET)	-3.186*	.426	.000
	Control Group (LNRET)	5.295*	.545	.000
Control Group (LNRET)	Experimental Group 1 (IRET)	-8.482*	.565	.000

***The mean difference is significant at 0.05 level**

Results from Table 5 show that at 0.05 level of significance, there were significant differences in the mean conceptual understanding scores in the three groups. There was significant difference of 0.000 between experimental group one and experimental group two, there was also a significant difference of 0.000 between experimental group one and control group and a significant difference of 0.000 between experimental group two and the control group in favour of the experimental groups. It therefore means that, the treatment had significant effects on students conceptual understanding of photosynthesis and respiration in plants. The null hypothesis was therefore rejected.

Hypothesis Two:

There will be no significant difference in the conceptual understanding of male and female students taught using inquiry method with refutational text, inquiry method with non-refutational text and lecture method with non refutational text in photosynthesis and respiration in plants.

Table 6 presents the summary of mean scores and standard deviation and conceptual understanding of male and female students in the three groups.

Table 6: Summary of Mean and Standard Deviation of Male and Female Student's Conceptual Understanding after Treatment.

Groups		N	Mean	Std. Deviation
Experimental Group 1 (IRET)	Male	31	12.13	1.893
	Female	16	11.56	1.861
	Total	47	11.94	1.881
Experimental Group 2 (INRET)	Male	45	8.71	2.222
	Female	15	8.87	3.091
	Total	60	8.75	2.440
Control Group (LNRET)	Male	13	3.62	1.938
	Female	9	3.22	2.333
	Total	22	3.45	2.064

***Significant at P≤0.05**

Results in Table 6, shows differences in the mean scores for male and female students' conceptual understanding in the three groups in test on photosynthesis and respiration in plants. The means scores for group one males and females were 12.13 and 11.56 respectively, 8.71 and 8.87 for males and females respectively in group two and 3.62 and 3.22 for the males and females in the control group respectively. ANCOVA was employed to determine the significant difference and result is presented in Table 7.

Table 7: ANCOVA Results for Male and Female Students Conceptual Understanding after Treatment.

Groups		Type III Sum of Squares	df	Mean Square	F	Sig.
Experimental Group 1	Corrected Model	10.913[a]	2	5.456	1.581	.217
	Intercept	1099.921	1	1099.921	318.617	.000
	Understanding at pretest	7.526	1	7.526	2.180	.147
	SEX	3.593	1	3.593	1.041	.313
	Error	151.896	44	3.452		
	Total	6859.000	47			
	Corrected Total	162.809	46			
Experimental Group 2	Corrected Model	51.051[b]	2	25.526	4.847	.011
	Intercept	572.624	1	572.624	108.726	.000
	Understanding at pretest	50.779	1	50.779	9.642	.003
	SEX	7.097	1	7.097	1.348	.251
	Error	300.199	57	5.267		
	Total	4945.000	60			
	Corrected Total	351.250	59			
Control Group	Corrected Model	2.459[c]	2	1.230	.269	.767
	Intercept	83.333	1	83.333	18.200	.000
	Understanding at pretest	1.637	1	1.637	.358	.557
	SEX	.897	1	.897	.196	.663
	Error	86.995	19	4.579		
	Total	352.000	22			
	Corrected Total	89.455	21			

The ANCOVA results displayed on Table 7, show that after treatment, there was no significant difference in the mean conceptual understanding scores between

male and females in the experimental group one {F (df;1, 44) =1.041}, not significant at 0.313, experimental group two {F (df;1,57) = 1.348} not significant at 0.251 and control group {F (df;1, 19) =1.196} not significant at 0.196. Hence, there was no significant difference in the conceptual understanding of photosynthesis and respiration in plants between male and female students' and the treatment they were exposed to. Conclusively, the hypothesis of no significant difference in conceptual understanding of photosynthesis and respiration in plants between male and female students taught with the teaching strategies was retained.

Discussion of Results

The null hypothesis two was rejected because a significant difference was observed in the students conceptual understanding of photosynthesis and respiration in plants between students taught using IRET, INRET and LNRET. This finding suggested that the students in the experimental groups who were taught with IRET and INRET were able to reconstruct the misconceptions they had to align with scientific views. This finding supports the findings from the researches carried out by Guzzetti et al, (1997), who noted that refutational texts have the capability to improve conceptual understanding probably because of their ability to create cognitive conflict in the readers. Diakidoy et al, (2003), posited that students' who read refutational texts performed better than students who read non-refutational texts. Another reason for the significant difference observed could also be attributed to the use of inquiry teaching method adopted for teaching the texts in the two experimental groups. The students taught with INRET performed better and had better conceptual understanding more than the students' taught with LNRET even though both groups used non-refutational texts of the concept of photosynthesis and respiration in plants. These findings support those of Dole (2000), Nurshamshida et al, (2010) Veloo et al, (2013) and Vlassi et al, (2013) who posited that inquiry is effective at promoting conceptual change. Their findings revealed that the inquiry-based teaching strategies are able to stimulate excitement among students when learning science. The statistical analysis showed a significant supremacy of the guided inquiry against the traditional teaching method for the teaching of the structure of matter. As hypothesized, the findings show the superiority of the refutation structure in learning new scientific concepts. This outcome is in line with most previous studies that have investigated offline products of learning from refutation text with students of different grade levels (Diakidoy et al., 2003; Hynd, McWhorter, Phares, & Suttles, 2004; Mason et al., 2008).

The results on hypothesis four established that there was no significant difference of on the conceptual understanding of male and female students who were taught using IRET and INRET. Therefore, the difference in sex did not play a role on students' conceptual understanding of photosynthesis and respiration in plants using IRET and INRET. Additionally, sex difference can be one of the key factors

affecting science achievement. Students' gender difference in science achievement generates much attention and debate. Gentry et al. (2002) reported that the elementary school students were more interested in classroom activities than the middle school students. The girls were also more interested in classroom activities and they enjoyed more than the boys. This is consistent with the works of Çakır et al. (2002) who found that the concept mapping based instruction and the conceptual change texts based instruction caused significantly better acquisitions of scientific conceptions related to acid and base concepts than the traditional instruction. There was no statistically significant mean difference between boys and girls in the students' achievement on the human circulatory system, and attitudes towards biology. However, the data from this current study showed that sex had no effect on the students' conceptual understanding of the concept of photosynthesis and respiration in plants.

Conclusion

Most students have several misconceptions on the concept of photosynthesis and respiration in plants before treatment. It can therefore be concluded that instructions on Inquiry and Refutational Texts is an effective strategy in restructuring misconceptions compared to the tradictional method. The students taught using IRET, INRET had a better conceptual understanding of photosynthesis and respiration in plants when compared to students' taught with LNRET. This finding suggested that the students in the experimental groups who were taught with IRET and INRET were able to reconstruct the misconceptions they had to agree with scientific views.

It was also established that there was no difference in the conceptual understanding of male and female students who were taught with IRET, INRET and LNRET. Therefore, it can be inferred that the sex of students does not influence their conceptual understanding of photosynthesis and respiration in plants.

It can therefore be concluded that the instructional package for the experimental groups were effective in clearing misconceptions and improving conceptual undetstanding of the concept of photosynthesis and respiration in plants when compared to the traditional method.

Recommendations

The following recommendations were proffered;

1. Teachers should spend sufficient time to explore the likely misconceptions that students may have prior to teaching any new concepts in biology and other science subjects generally. They can consider the students' existing conceptions or misconceptions in biology/science in order to select and organize students' intended learning outcomes in biology/science.

2. Curriculum planners should ensure that the aims and objectives in secondary school science curriculum and syllabi indicate that students' misconceptions in topics like photosynthesis and respiration in plants are identified and stated as part of the teachers' lesson plan and lesson notes.
3. The power of refutational text as a conceptual change agent must be recognized by publishers, editors, and authors, so that the refutation text structure will appear more frequently in children's science information books.
4. The educational institutes should arrange workshops, trainings, inquiry sessions, discussions and seminars on conceptual understandings and misunderstandings of students at different levels to sensitize the teachers about the existence of manifold misconceptions about each concept of biology in particular and in science generally.
5. The curriculum planners and the ministry of education must deliberately be sensitized and made to be aware of the importance and effectiveness of the refutational text because of its ability to create conceptual change in clearing misconceptions and improving the readers' performances during examinations.

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