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The Comparative Effects of Cyclic Inquiry Model, Conceptual Change Text, and Traditional Instruction on Students' Understanding of Photosynthesis and Respiration in Plants

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ABSTRACT

The aim of this study was to explore the effects of the cyclic inquiry model, conceptual change texts, and traditional instructions on promoting understanding of photosynthesis and respiration in plants. The data were obtained from 33 students in the first experimental group taught with cyclic inquiry model (CIM), 34 students in the second experimental group taught with conceptual change texts (CCT), and 34 students in the control group taught with traditional instruction (TI). After instruction, data were analyzed with analysis of covariance (ANCOVA) using pre-test scores and logical thinking scores as covariates. The results indicated the cyclic inquiry model (CIM) and conceptual change texts (CCT) treatment groups significantly outperformed the traditional instruction (TI) group in understanding the photosynthesis and respiration in plants. A statistically significant difference between two experimental groups was found in favor of the of cyclic inquiry model CIM.

1. Introduction

Research on students' understanding of scientific concepts in the past few decades has indicated that students hold many ideas that are different from those generally accepted by scientists. In the last two decades, there has been a number of studies that investigated students' misconceptions about photosynthesis and respiration in plants at middle and secondary schools^[1-7].

For example, Haslam & Treagust^[7] diagnosed understanding of photosynthesis and respiration in plants. The sample of the study consisted of 441 Australian students (grades 8-12). The results highlighted the consistency

of the students' misconceptions across secondary year levels and indicated that a high percentage of secondary school students do not comprehend the nature and function of plant respiration and have little understanding of the relationship between photosynthesis and respiration in plants. Ozay & Oztas^[6] studied the misconceptions held by 88 grade 9 students' (14-15 years old) in Turkey about photosynthesis and plant nutrition. Results revealed that students have conflicting, and often incorrect, ideas about photosynthesis, respiration and energy flowing. Svandova^[3] investigated the common misconceptions of 108 lowest secondary school students (age 11-16 years)

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in Czech Republic. The research showed that the students have many misconceptions about photosynthesis and respiration. Ameyaw^[2] investigated 150 Senior High School (SHS) students' conception of photosynthesis and respiration in Ghana. The results gathered from the study showed that 31.5% of students did not know that glucose is the raw material for cellular respiration, and that water is produced as a by-product in aerobic respiration. Likewise, 23.6% and 29.9% of the respondents said Adenosine Tri-phosphates (ATPs) are not released at the end of aerobic respiration, and that anaerobic respiration does not occur in both plants and animals respectively. It also came to light that 36.7% of the respondent did not know that anaerobic respiration does not require oxygen for the reaction to proceed. Susanti^[1] investigated the misconceptions of Biology education of Sriwijaya University in Indonesia about photosynthesis and respiration. The sample of the study consisted of 58 students'. The results indicated that: photosynthesis occurs continuously (37.9%), energy used for photosynthesis are light and heat energy (34.5%), plants take CO₂ to respiration (47%), plants carry on respiration in the absence of light for photosynthesis (22.4%), respiration in plants occurs only in leaf cells (76.4%), and only animals that take O₂ of photosynthesis to respiration (68.9%).

Alternative strategies have been offered by researchers to enhance meaningful learning in science. According to Novak^[8], Conceptual change is necessity for meaningful learning to occur. The four conditions that are necessary for conceptual change to occur: (a) there must be dissatisfaction with existing conceptions, (b) the new conception must be intelligible, (c) the new conception must appear initially plausible, (d) the new conception must be fruitful^[9]. One of the most successful techniques based on conceptual change approach is the use of conceptual change text^{[10][11]}. In these texts, the students are asked explicitly to predict what would happen in a situation before being presented with information that demonstrates the inconsistency between misconception and the scientific conception. Several studies have reported the effectiveness of conceptual texts on creating conceptual change and promoting meaningful learning in students regarding many science^{[5][12-17]}.

Inquiry-based learning model has been also used extensively in science education to promote meaningful learning, beside the use of conceptual change, text prepared according to a conceptual change approach. The inquiry-based teaching approach is one of most successful approaches, and supported on knowledge about the learning process that has emerged from research^{[18][19]}. In inquiry-based science teaching, students engaged in many

of the activities and thinking processes that scientists use to produce new knowledge. Teachers encourages by science educators to replace traditional method instructional practices, such as emphasis on textbooks, lectures, and scientific facts, with inquiry based approaches that (a) engage student interest in science, (b) provide opportunities for students to use appropriate laboratory techniques to collect evidence, (c) require students to solve problems using logic and evidence, (d) encourage students to conduct further study to develop more elaborate explanations, and (e) emphasize the importance of writing scientific explanations on the basis of evidence^[20]. Sandoval & Reiser^[21] indicated that in order to build the inquiry-based classroom environment must construct a community of practice like the scientists work. The students take actions as scientists did, experiencing the process of knowing and the justification of knowledge, in authentic inquiry-based activities.

Currently, although studies in science education revealed the value of inquiry-based learning, teaching models of inquiry-based learning are diverse^{[22][23][24]}. For instance, the inquiry cycle developed by Bruce and colleagues^{[25][26][27]} consists of five stages: asking, investigating, creating, discussing, and reflecting (see Figure 1). Each stage in this inquiry cycle – seen as a process that provides learners with context-situated and content-specified learning experiences that help them explore the world in a connected fashion – can be embedded, interrelated or independent, depending on the situated learning needs. So, this cycle embraces an exploratory approach that motivates learners who have problems to be solved; engages learners through investigation, hands-on practice, collaboration, and dialogues; and stimulates learners' construction of meaning through the process of solving problems and then posing emergent questions.

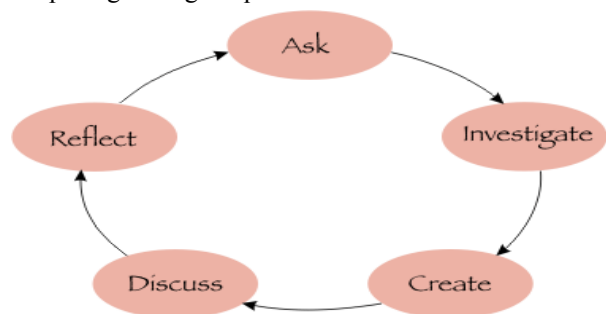


Figure 1. The inquiry cycle

The five stages in the process - ask, investigate, create, discuss, reflect-overlap, and not every category or step is present in any given inquiry. Each stage can be embedded in any of the others, and so on. In fact, the very nature of inquiry is that these phases are mutually reinforcing

and interrelated. Together, they comprise a cycle that can be used to inform and guide educational experiences for learners.

Ask

This stage, and the entire inquiry cycle begins with the desire to discover. Meaningful questions are inspired by genuine curiosity about real-world experiences and challenges^[25]. The students raise and ask questions about the topics or issues, and then the teacher prepared a list of all questions related to the topics raised by students, and presents these questions to students to answer.

Investigate

Curiosity turns into action. Students gather information, study, design an experiment, observe, or interview. The student may recast the question, refine a series of query, or plunge down a new path that the original question did not, or could not, anticipate. The information gathering stage becomes a self-motivated process that is owned by the engaged student^[28]. Investigating encourages students by to examine their topics using various sources of information and then plan out their creation and offers them an opportunity to navigate their inquiry^[25].

Create

The student begins to make connections, as the information gathered in the investigation stage begins to coalesce. The ability to synthesize meaning at this stage is the creative spark that forms all new knowledge. The student now undertakes the creative task of shaping significant new thoughts, ideas, and theories outside of his/her prior experience^[29]. On this step each group of students Writes a report includes all the knowledge, ideas, and information that have been discovered, and new conclusions reached that might be contribute to answering the main questions^[30].

Discuss

Through discussion (or dialogue), construction of knowledge becomes a social enterprise; Students share their ideas and ask others about their own experience and inquires^[28]. the discussion involves listening to the others and articulating their own understanding, helps them to achieve meaningful knowledge^[25].

Reflect

Reflection is taking the time to look back at the question, the research path, and the conclusions made. The student steps back, takes inventory, makes observations, and possibly makes new decisions^[29]. Has a solution been found? Do new questions come into light? What might those questions be?

Research has documented the effectiveness of cyclic inquiry model on enhancing meaningful learning in students regarding many science concepts^[30-33]. For example

Pansan & Nuangchalem^[32], compared learning achievement, science process skills and analytical thinking of fifth grade students who learned by using organization of project-based and inquiry-based learning activities. The sample used in the study consisted of 88 fifth grade students. Results revealed that the plans for organization of project-based and inquiry-based learning activities were appropriately efficient and effective. The students in both groups did not show different learning achievement, science process skills and analytical thinking. Albaaly^[30] explored the effect of using the cyclic inquiry model in developing some of science processes and achievement in science among a sample consisted of 93 fifth grade students in Saudi Arabia. The results indicated that the cyclic inquiry model significantly outperformed the traditional treatment on the tests of science processes and the achievement in science. Abu al-Rukab^[31] investigated the effect of cyclic inquiry model on the acquisition of scientific concepts and scientific thinking skills among a sample consisted of 147 fifth grade students in Jordan. Results indicated that there were statistical significant differences in acquisition of scientific concepts and scientific thinking skills attributed to the instructional model in favor of the cyclic inquiry model.

No research encountered in the literature that explores and compares the cyclic inquiry model instruction on conceptual understanding. Although the use of conceptual changes texts in science instructions are popular^[12-17].

In an effort to promote conceptual understanding in science classroom, this research was conducted to examine the effects of the cyclic inquiry model (CIM), conceptual change texts (CCT), and traditional instruction (TI) on promoting understanding of photosynthesis and respiration in plants. It can be said that the main difference of the present study when compared to other studies is due to the cyclic inquiry model instruction factor on the conceptual understanding of photosynthesis and respiration in plants.

Statement of problem

This study was conducted to explore the effects of the cyclic inquiry model (CIM), conceptual change texts (CCT), and traditional instruction (TI) on promoting students' understanding of photosynthesis and respiration in plants. This topic is a fundamental part of biology curriculum and is considered abstract and difficult for students and teachers. Many researchers discussed the difficulties of teaching and learning photosynthesis and respiration in plant, others focused on students' conception related to photosynthesis and respiration. Less attention has been given to developing strategies or methods to eliminate these difficulties and remediate misconceptions, and improving photosynthesis and respiration in plants instruc-

tion in basic biology classes. To improve understanding in basic biology classes, it is worthwhile to explore the effect of mode of instruction and cognitive variables on understanding of photosynthesis and respiration in plants. The main question is whether there are significant differences among the effects of CIM instruction, and CCT instruction, and TI instruction on students' understanding of photosynthesis and respiration in plants concept when photosynthesis and respiration in plants concept pre-test and TOLT scores are controlled as covariates.

2. Methodology

2.1 Sample

A total of 101 ninth- grade students, aged between 14 and 15 years (M=14.24, SD 0.42), enrolled in three classes in a basic-school in an urban area in Jordan. Each of the three classes instructed by the same Biology teacher (8 years of teaching experience) were randomly assigned as a CIM class (n=33), a CCT class (n=34), and a traditional class (n=34). Students in this study can be characterized as having middle-to high socioeconomic status (SES). Each class received identical syllabus-prescribed learning content. All the students fully participated in the study by attending classes, and completing the pretest and the posttest.

2.2 Instruments

The Photosynthesis and Respiration in Plants Concept Test

In this study the test developed by Haslam & Treagust^[7] was used to determine students' conceptual understanding of photosynthesis and respiration in plants. It included a 13-item two- tier multiple choice test. The first tier of each item examined the content knowledge with two, three and four alternatives. The second tier consisted of reasons for the first tier, including a scientifically correct answer and three misconceptions^[7]. A student's answer to an item was considered correct if the student answered both the content part and the reason part correctly. The test items were translated and adapted into Arabic. Content validity of each item was determined by a group of experts in science, science education, measurement and evaluation. The classroom teacher also analyzed the relatedness of the test items to the instructional objectives. The reliability coefficient computed by Cronbach's alpha estimates of internal consistency of this test was found to be 0.78, when both parts were analyzed. The test was administered to students in the three groups as a pretest, and post-test, to assess the students' conceptual understanding of photosynthesis and respiration in plant concepts over time.

The Test of Logical Thinking (TOLT)

In this study the test of logical thinking (TOLT), orig-

inally developed by Tobin & Capie^[34], was used to determine the formal operational reasoning modes. The test was translated and adapted into Arabic by Abu Ruman^[35]. It consists of 8 items designed to measure controlling variables, proportional, probabilistic, co relational, and combinational reasoning. The 8 items include two parts: an answer and a justification for the selected answer. The correct answer is the correct choice plus the correct justification. The internal consistency of the test was determined to be 0.82 using Conbach's alpha.

2.3 Treatment

This study was conducted over 3-week period in the first semester of the academic year 2017-2018. A total of 101 ninth -grade students were enrolled in three biology classes in a basic-school. Three classes, taught by the same biology teacher (8 years of teaching experience), were randomly assigned as a CIM class, a CCT class, and a traditional class. The classroom instruction for each group had two 45-minute periods per week. Students in all groups were exposed to same content for the same duration, and topic related to target concepts was covered as a part of the regular curriculum. Equal opportunities were considered to perform the activities in each group.

Students in the first experimental group were instructed with CIM instruction. Two separate CIM lessons, one for photosynthesis, one for respiration in plants, were designed by focusing on students' misconceptions and the objectives of the lesson. Lesson plans, including the objectives and detailed explanations of each phase of the CIM, were prepared as a guide. In the first phase (Ask) students' curiosity was prompted by asking questions about photosynthesis and respiration. It is important that students formulate their own questions because they then explicitly express concepts related to photosynthesis and respiration. The second phase (Investigate) was designed to lead students to seek and create. Students or groups of students collect information, study, collect and exploit resources, experiment, look, and interview, draw....The third phase (Create) permitted students to merge collected information, they start making links. The ability to synthesize meaning is the spark which creates new knowledge. Students may generate new thoughts, ideas and theories that are not directly inspired. The fourth phase (Discuss) gave students the opportunity to share their ideas with each other, and ask others about their own experiences and investigations, they begin to understand the meaning of their investigations, comparing notes, discussing conclusions and sharing experiences. The final phase (Reflect) which requires taking time to look back, think again about initial question, the path taken, and the actual conclusion. Students look back and may take some new decisions.

Students in the second experimental group worked with CCT instruction method. Two conceptual change texts were prepared by the researcher considering four conditions proposed by Posner et al.,^[9] dissatisfaction, intelligibility, plausibility, and fruitfulness. In each of the texts, students were introduced to questions and possible answers that may include misconception held by the student. Because of this technique, students were expected to be dissatisfied with their current conceptions. Then, scientifically accepted explanations that are more plausible and intelligible were described. Also, examples and figures were inserted into the texts for further help for students to comprehend the scientific concepts and realize the limitations of their own ideas.

Students in the control group were taught the topics of photosynthesis and respiration in plants by the teacher upon the basis of a lecture /discussion methods. The teaching strategy mainly relied on explanation by the teacher. Students read the topic from their textbooks in the classroom. Then, the teacher explained the concepts related to photosynthesis and respiration in plants by drawing examples on the board and illustrating important facts in the order as it appeared in the textbook. Specifically, the teacher used the chalkboard to write notes about the definitions of concepts, such as metabolism, enzyme, chloroplast, chlorophyll, mitochondria, ATP, cellular respiration, fermentation. After the teacher's explanation, concepts were discussed by the teacher via asking direct questions. The remaining time was taken up with the solving of various problems. The lesson ended with the students answering the questions orally. The main idea behind this teacher-centered instruction was to provide students with clear and detailed information. Students appeared to play a fairly passive role. Such instruction did not take students' misconceptions into account (see Appendix A).

3. Results

Descriptive statistics concerning the variables of the study were presented in Table 1. The table shows the means and standard deviations of the study variables. The mean scores on the TOLT, and the pretest reflected that students in each group had a medium level of formal-reasoning ability, and inadequate relevant prior knowledge, respectively.

Table 1 Means and Standard Deviations of the Variables

Variable	CIM n=33		CCT n=34		TI	
	M	SD	M	SD	M	SD
Pre-test	2.54	0.94	3.06	1.41	3.65	1.07
TOLT	3.48	1.17	3.85	1.08	3.82	1.38
Post-test	7.03	2.35	6.76	2.61	5.85	1.52

Pre-test= *pre photosynthesis and respiration concept*

test, TOLT= test of logical thinking, Post-test= post photosynthesis and respiration concept test.

To establish if there were significant differences in students' posttest means attributable to treatment, analysis of covariance (ANCOVA) was used to assess the effect of each treatment on students' understanding of Photosynthesis and respiration in plant concept test. ANCOVA was used in this study as it primarily served to adjust initial differences between groups attributed to the covariates. Table 2 summarizes the ANCOVA comparing the mean posttest scores of the performance of students in all groups.

Table 2 Summary of ANCOVA Comparing the Mean Posttest Scores of Students in the Three Groups

Source	SS	df	F	p	η^2
Pre-test	66.83	1	66.83	0.000	0.184
TOLT	45.519	1	45.519	0.000	0.133
Treatment	73.429	2	36.714	0.000	0.196
Error	297.3	96			

The analysis indicated significant effects for the covariates pretest score, $F(1, 96)=66.83, p=0.000$, and TOLT score, $F(1, 96)=45.519, p=0.000$. The results also revealed a significant treatment effect, $F(2, 96) = 36.714, p=0.000$ in favor of the experimental groups. Students in the experimental group who were engaged in the CIM instruction demonstrated better performance over the control group TI students ($p < 0.05$). Similarly, students who received CCT instruction scored significantly higher than students taught by traditional instruction TI with respect to understanding of photosynthesis and respiration in plant concepts ($p < 0.05$), and students who received CIM instruction scored significantly higher than students taught by CCT instruction ($p < 0.05$). Strength of the relationship between the treatment and posttest scores was strong $\eta^2=0.196$.

In order to determine which groups accounted for the difference found in the analysis of variance, a posterior comparison was made. The Bonferroni multiple comparisons was used to analyze paired contrast (Table 3). The photosynthesis and respiration in plants concept test adjusted mean scores of the two experimental groups engaged in cyclic inquiry model and conceptual change text instruction were significantly higher than the mean of the control group ($p < 0.05$). The CIM group produced significantly higher adjusted mean score on the photosynthesis and respiration in plants concept test than did the CCT group.

Table 3 LSD Comparisons between Instruction Methods with Respect to Adjusted Mean Scores on the Photosynthesis and Respiration in Plants Concept Test

Comparisons*	Computed value	p
1 vs 2	0.88*	0.005
1 vs 3	2.23*	0.000
2 vs 3	1.35*	0.000

* $p < 0.05$. CIM 1: cyclic inquiry model. CCT 2: conceptual change text. TI 3: Traditional instruction.

When the proportion of correct responses and misconceptions determined by item analysis for the experimental and control groups was evaluated for both pre-posttests. Remarkable differences between the groups in favor of the experimental groups were found. The average percentage of students in cyclic inquiry model group holding the scientifically correct view had risen from 18.85% to 54.08%, a gain of 35.23%, the percentage of correct response of the students in conceptual change text group had increased from 23.54% to 52%, a gain of 23.46% after treatment. The percentage of correct responses of the students of the control group, however, increased from 28.08% to 45%, a gain of 16.92%. However, these results indicate low level of conceptual understanding even after the treatment.

Analysis of results indicated that students in experimental and control groups have many misconceptions about photosynthesis and respiration in plants. For instance, most students' conceptions were different from scientific meaning. Many students still had misconception "that oxygen gas is given out in largest amount by green plants in the presence of sunlight, because green plants only photosynthesize and do not respire in the presence of light energy". Research also, indicated that students believed that "green plants respire only at night, when there is no light energy because cells of green plants can photosynthesize during the day when there is light energy". In addition, several students had the misconception that "carbon dioxide is given off green plants in large amounts when there is no light energy at all because green plants respire only when there is no sunlight energy". Another misconception held by students was that "the most important benefit to green plants when they photosynthesize is the removal of the carbon dioxide from the air". Moreover, several students thought that photosynthesis takes place in green plants in the presence of light and respiration takes place in green plants only when there is no light because green plants photosynthesize during the day and respire at night. A list of common misconceptions identified in the study were mentioned in Appendix B. Many of these misconceptions are typical misconceptions identified by other studies e.g. [7, 15, 16, 36].

4. Discussion

The purpose of this study is to investigate the effects of three types of instruction, the cyclic inquiry model (CIM), the conceptual change text instruction (CCT), and traditional instruction (TI), on 9th grade students' understanding of photosynthesis and respiration in plants. The photosynthesis and respiration in plants concept test developed by Haslam & Treagust^[7] was administered to determine

students' understanding of photosynthesis and respiration in plants. The test of Logical Thinking (TOLT) was used to determine the formal reasoning ability of students. The TOLT and pretest scores used as covariates in this study served mainly to reduce error variance. Results revealed that both covariates had significant effects on understanding of the target concept. This result is in agreement with previous studies results in the literature indicating that reasoning ability and prior knowledge have great influence on students' understanding of science concepts^[37-40]. For example, Dogru-Atay & Tekkaya^[37] reported that students' logical thinking ability accounted for a significant portion of variation in genetics achievement. BouJaude et al.,^[38] pointed out that the main predictor of performance on conceptual understanding of chemistry was formal operational reasoning.

The results showed that the students in both cyclic inquiry model (CIM) and conceptual change texts (CCT) groups performed significantly better than students in the traditional instruction group with respect to photosynthesis and respiration concepts. The emphasis was given to students' misconceptions in both experimental groups. Students were engaged in activities that are intended to capture their attention, get them thinking about the subject matter, raise question in their minds, stimulate thinking and activate their prior knowledge. By these activities the evidence that students initial conceptions are insufficient and supported only partial understanding of the concepts were also provided.

What inquiry based learning (CIM) has in common is the active role of the students. Students are actively engaged in constructing knowledge. During each phase of the cyclic inquiry model, students are actively questioning and formulating problems, manipulating materials, observing and recording data, or analyzing data. By reflecting science processes or inquiry skills the cyclic inquiry model, allowed students to become active members in the process as they construct and understand scientific concepts. Because of the strength of cyclic inquiry model, students can see links among concepts and make connections between new learned concepts and existing concepts in their cognitive structures. Many interrelated facts and ideas are included in photosynthesis and respiration in plant concepts. Learners must relate the ideas and facts that form the concept to achieve meaningful conception of topics. In inquiry based learning the strategies used supported a change in students from passive to active learners. The activities involved in the cyclic inquiry model helped students recognize their prior conception, and helped them meaningfully learn through the connections among concepts and through developing reasoning skills.

This result is consistent with previous studies^{[30][31]} Similarly, results regarding the effectiveness of conceptual change text instruction (CCT) can be explained as follows: students activate and revise their prior knowledge and struggle with their misconceptions by involvement in activities. For example, students in the conceptual change text instruction became dissatisfied with their existing conceptions, which enabled them to accept better explanations to the problem that was introduced. In this way, students think about their prior knowledge and reflect on it. The conceptual change text definitely dealt with students' misconceptions. It required students to construct an alternative schema to replace the misconception schema. The essential part of conceptual change text instruction was the social interaction provided by the teacher guided discussions. The students discussed the conceptual change texts with the teacher. The instruction encouraged intensive teacher-student interaction and student-student interaction, such a discussion environment allowed students to focus on learning, conceptual understanding, and mastering the task. However, students focused on concepts related to the subject that requires less conceptual restructuring students in the traditional Instruction group. This result is consistent with numerous previous studies investigating the effectiveness of the conceptual change text instruction^[12-17].

The present study, However, has limitations to be considered. The study was conducted at a public school in an urban area by using whole classes. Data from other school districts and from different school types might give different findings. This study was limited to cell activities unit and 101 ninth graders. The results, therefore, may not be reliable if generalized beyond students enrolled in a similar situation.

5. Conclusion

The cyclic inquiry model instruction (CIM) and conceptual change text-oriented instruction (CCT) caused a significantly better acquisition of photosynthesis and respiration concepts and elimination of alternative conception than the traditional instruction (TI). This result supports previous research reporting that instructional strategies, which take into consideration the active role of the learner, and pre-existing concepts in the learners' cognitive structure, can promote better conceptual understanding. Additionally, this result supports the thought that it is not easy to eliminate misconceptions just by employing a teacher-centered and textbook-oriented instruction. It is necessary to eliminate misconceptions with the help of different methodologies that promote the active role of the learner rather than the traditional instruction, to create conceptual understanding and

promote meaningful learning.

The findings of this study indicated that sound understanding could be reached with suitable instructional method. This study suggested the use of cyclic inquiry model and conceptual change oriented instruction as an alternative approach to traditional methods to remediate misconceptions.

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Appendix A

Comparison of Instructional Methods

Cyclic Inquiry Model Instruction

Ask	The teacher introduced concepts and issues about the subject (photosynthesis for example) of the lesson, and encourage students to ask themselves about concepts and issues they find important and engage in conversation about these issues with their peers.
Investigate	Curiosity turn into Action. Students carry out experiments and inquiry activities, and practice different science processes skills in order to gather knowledge and information to answering questions in the previous stage.
Create	Students construct meaning by engaging in hands-on learning activities, in other words, students learn to transform the thought developed earlier through asking and investigation into substantive creation of meaning.
Discuss	Students share their ideas and ask others about their own experience and inquires. The discussion involves listening to the others and articulating their own understanding , helps them to achieve meaningful knowledge.
Reflect	The teachers gives students time to look back at initial questions, the research path and the conclusions made, and then invoke further questions derived from the reflection of current experience.

Conceptual Change Text Instruction

The texts were given to the students before the instruction.

The teacher directed the students to read it before the class hour and bring it to the class.

Students were informed about the new instruction, the nature of the conceptual change text, and how they would use it during the instruction.

Students read a paragraph in which a question was posed to arouse students' interest in the subject and to analyze their pre-conceptions.

Students shared their ideas about the answer with the class. The teacher did not intervene and did not give any feedback during this process.

Answers that are not scientifically correct (misconceptions) about the concept that were provided in the text were read aloud by one of the students.

Students were asked to compare their conceptions with these misconceptions.

The scientifically correct explanations of the concept that are intelligible and plausible were provided to guide students in considering why the misconceptions could be wrong.

The teacher asked whether anything related with the explanation surprised the students to help the students reconstruct the concepts.

Images, figures, and pictures were used to help students visualize the concepts while reading the text.

In addition, the history of science, such as cell activities, equations of photosynthesis, cellular respiration, and fermentation.

Traditional Instruction

Teaching strategy relied on teacher's explanation. The teacher used the chalkboard to write notes about the definitions of the concepts, such as; cell activities, photosynthesis, enzyme, cellular respiration, fermentation, and write equations related with photosynthesis and cellular respiration.

After the teacher's explanation, concepts were discussed by teacher-directed questions.

The focus of the instruction was on problems related with cell activities, photosynthesis, and cellular respiration.

No experiments or hands-on activities were performed by the students related with the topics.

Appendix B

Common misconceptions identified by Photosynthesis and Respiration in plants Concept Test

Misconceptions

Carbon dioxide is used in respiration which only occurs in green plants when there is no light energy to photosynthesize

Respiration in plants takes place in the cells of the leaves only

Respiration is the exchange of carbon dioxide and oxygen gasses through plant stomata

Green plants take in carbon dioxide and give off oxygen when they respire

Green plants do not respire in the presence of light energy, they respire only at night when there is no light energy.

Green plants respire only during daylight because green plants do not respire, they only photosynthesize

Photosynthesis provides energy for plant growth

Plants respire when they cannot obtain enough energy from photosynthesis and animals respire continuously because they cannot photosynthesize