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Learning Cycle Approach (LCA) for Effective Teaching and Learning of Glycolysis and the Krebs Cycle

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Abstract: This study is an inquiry into the outcome of Learning Cycle Approach (LCA) on Senior High Students' understanding of Glycolysis and the Krebs cycle at the Odorgonno Senior High School of the Ga South District in the Greater-Accra Region of Ghana. The two concepts were explained using either Conventional Teaching Approach (CTA) or Learning Cycle Approach (LCA). The investigation was to find out whether the LCA could enhance students' academic achievement better than the CTA mostly used by some SHS Science teachers. A design involving two cohorts assigned as Group A and B with a total population of 80 was used for the study. Group 'A' was the quasi-experimental group upon which the LCA was applied in teaching glycolysis and the Krebs cycle whereas group 'B' was used as the control group taught using the CTA. Data gathered from both pre- and post-interventional tests were analysed using SPSS version 18. The pre-interventional test revealed that both groups lacked conceptual understanding of the processes involve in cellular respiration, particularly, glycolysis and the Krebs cycle. The outcome of the analysis conducted on the post-interventional scores of the two cohorts revealed that the experimental group achieved higher conceptual understanding than the control group. Hence, the LCA is a good teaching and learning approach for facilitating lessons in glycolysis and the Kerbs cycle.

Keywords: Krebs cycle, Glycolysis, SHS, Learning Cycle Approach (LCA), Conventional Teaching Approach (CTA)

Introduction

Researchers have been working and making inquiries into how learners interact with their environment, store information, retrieve and use this same information in a way that will be useful to society (Abimbola, 1987). The findings of some of these studies have shown that significant section of students find it difficult to comprehend and assimilate concepts been taught by their teachers (Jegede, 1992; Salau, 1996). This situation has brought about poor student achievement in science and this has alarmed governments, educational authorities and individuals (Akpan, 1996). As a result some concern stakeholders have directed their attentions towards how to find the cause and remedy to students' inability to store and make use of information at their disposal (Abimbola, 1987). The findings of some of such studies have linked poor students' academic achievement to many factors including poor teacher preparation coupled with poor teaching skills among science teachers and for that matter, biology teachers (Okebukola, 1997; STAN, 1992). Similarly, studies have been conducted on how to find remedy to students' poor achievement in comprehending internal respiration, particularly, glycolysis and the Krebs cycle. Some of the approaches used to remedy students' difficulties encountered in learning of internal respiration, particularly, glycolysis and the Krebs cycle include such methods as role play **(**Ross, Pauline, Tronson, Deidre, Ritchie, & Raymond**,** 2008), Hans Krebs, and the Puzzle Cellular Respiration (Holmes, 1993). However, it appears most of these methods were of more expert directed (teacher centeredness); a teaching-learning approach that promotes rote learning. As a result, a quest for more child centered approach has conceived this study which determined the effectiveness of learning cycle (a child-centeredness teaching and learning approach) on students' understanding in glycolysis and Krebs cycle. Learning Cycle Approach, an inquiry-based teaching approach which was developed by Karplus and Thier (1967) became useful for the study because of its learner centered nature. The original LCA developed by Karplus is based on three distinct phases of instruction which include:

(1) *Exploration* provides students with first hand experiences on science phenomena, (2) *Concept introduction* allows students to build science ideas

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through interaction with peers, texts, and teachers, and (3) *Concept application* asks students to apply these science ideas to new situations or new problems (Hanuscin & Lee, 2008). The LCA with its three phases used by several researchers has being revised as the 5-E model: Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 1997). The Engage phase of the 5-E is designed to mesmerize students' attention and elicit their prior knowledge about the concept(s), while the Evaluate phase is an opportunity for the teacher to assess students' progress, as well as for students to reflect on their new understandings. One of the remarkable researches that investigated the impact of the LCA is the work of Lawson, Abraham and Renner (1989). The study conducted by Lawson *et. al.* (1989) concluded that the LCA can lead to students' greater achievement in science, better retention of concepts, improvement of students' attitudes toward science and science learning, improvement of students' reasoning ability, and superior process skills than using the CTAs (Gerber, Cavallo & Merrick, 2001). Similarly, studies conducted by Ramsey (1993), also highlighted that the LCA can help teachers to incorporate important instructional goals into a developing conceptual 'storyline' that accommodates both selection and sequencing of learning opportunities. Moreover, research findings of the studies conducted by Rubba, (1992) and NRC, (1996) revealed that the LCA has been embraced in science teacher education as a suitable approach which is consistent with the goals of the *National Science Education Standards*. Therefore, it appears that the LCA is becoming more useful in enhancing students' conceptual understanding than the role play used by Ross, Pauline, Tronson, Deidre, Ritchie and Raymond**, (**2008), and that of Hans Krebs, and the Puzzle Cellular Respiration developed by Holmes, (1993). It was upon the above revelation (deficiency in the role play learning and, the Hans Kreb and the Puzzle Cellular Respiration) that this study based on the hypotheses given below is to find out the impact of LCA which has been given much attention by Abraham and Renner (1989), Lawson *et.al.* (1989), Hanuscin and Lee, (2008), Bybee, (1997) as well as Gerber, Cavallo and Merrick, (2001) on SHS students' understanding of glycolysis and the Krebs cycle.

Research Hypotheses

The following Null hypothesis was used for the study:

H_{01}. LCA has no significant effect on students' achievement in "Glycolysis and the Krebs cycle" at the SHS level than the CTA that has been used for decades.

H_{02}. There is no significant difference between the academic performance of students who received instructions through the LCA and those who received instructions through the CTA.

Methodology

The study used the quasi-experimental design to gather data from SHS Two (2) students' understanding of glycolysis and the Krebs cycle. The target population for the study was all second year SHS Biology students in the Greater Accra Region of Ghana. The accessible population was second year students who read biology as their elective area in Odorgonno Senior High School in the Ga south Municipality of the Greater Accra Region. The sample was made up of two cohorts with a total population of 80 students. These two intact classes were assigned randomly to one of the two approaches (either LCA or CTA) Odorgonno Senior High School was purposely sampled due to the fact that it is one of the Model Senior High Schools and also one of the Senior High Schools with well Science resources, and a mixed school as well. It was therefore selected through purposive sampling. According to Gray (1981), purposive sampling allows the Researcher to select respondents who he or she believes is appropriate for the study. As a result, the selection of Odorgonno Senior High School was appropriate for the study.

Validity of the Instrument

The instruments used for the study consisted of 20 test items in the pre-interventional test and 20 test items in the post-interventional test Exercise. Both items in pre- and post-tests exercises were validated by comparing what they were measuring to the rationale and the goals of the SHS biology syllabus. Instruments were also examined and validated by SHS teachers who are West African Examination Council (WAEC) biology examiners. Their inputs were used to correct errors that might influence the results. The items were also subjected to item analysis after conducting a pilot-test in Christian Methodist Senior High School which is in the Ga South Educational municipality of the Greater Accra Region. These exercises led to a review of some items and modifications of the instruments before using them for the study.

Reliability of the Instrument

Internal consistencies of the two instruments were also determined through pilot-testing at Christian Methodist Senior High School which was outside the Ga Central Municipality. The School was used for the pilot-testing because it is in the same category as Odorgonno Senior High School. Both Christian Methodist and Odorgonno Senior High School have similar characteristics in terms of science facilities and heterogeneous students' population. The internal consistencies of both pre-test and pilot test were determined using SPSS version 16.0. The pre-test and the post-test yielded alpha values of 0.72 and 0.81

respectively and this has been described by George and Mallery (2003) as good estimates.

Data Collecting Instruments

The following are the descriptions of the treatments administered to the two groups:

Group A: The Learning Cycle Approach

This group was the experimental group. The LCA was the instructional technique used to engage students in lessons designed to facilitate students' understanding in glycolysis and Krebs cycle. The 5E's approach of the learning cycle was used to stimulate and sustain students' interest in studying glycolysis and the Krebs cycle. During the 'Engage' stage, students in this group were engaged with activities designed to mesmerize students' attention and elicit their prior knowledge about glycolysis and Krebs cycle. These activities include riddles that elicited students previous conception on glycolysis and Krebs cycle. The Explore phase of the LCA gave opportunity for learners in groups to perform hands-on activities and did their own investigations to sample information on glycolysis and Krebs cycle. The 'Explain' phase of the 5Es in the LCA allowed members in within groups in the experimental class to explain their findings from the exploration they made about the glycolysis and Krebs cycle. The 'Elaborate' stage of the 5Es also focused the experimental students' attention on the connections between their prior knowledge and the new knowledge. The final phase of the 5Es used; the 'Evaluate' phase gave opportunity for the teacher to assess students' progress, as well as for students to reflect on their new understandings. The detail is presented in Appendix A.

Group B: The Conventional Teaching Approach

This group received teaching instruction on Glycolysis and the Krebs cycle through the conventional instructional method which has been described by some authorities as teacher-centred approach (Trilling & Fadel, 2009). Teachers act as all-knowing who teach students through talking and chalk board illustrations while students write the salient points in their note books. This method was used to present lessons prepared on glycolysis and the Krebs cycle to students in group B. The principal teaching techniques used in delivering the lesson include: verbal description, gestures as well as chalk board illustrations. The detail lesson hint is presented in Appendix B**.**

The instruments used for data collection were pre-test and post-test items.

Pre-test: The pre-test was a perception test which was labelled as 'SHS students' perception about glycolysis and Krebs cycle. The test items which were given to students in all the two cohorts contained items that tested students' previous knowledge on their basic conceptions about glycolysis and Krebs cycle. The responses provided by individual students were marked and the mean scores for each cohort was determined to verify whether students in the two cohorts have similar conceptual knowledge about glycolysis and Krebs cycle and whether they are of the same ability level before the application of interventions.

Post-test: This test instrument was named as 'SHS students' achievement test in glycolysis and Krebs cycle'. This instrument consisted of 15 items structured to determined the extent to which the interventions helped the respective students to comprehend the concept been taught. The data gathered were analysed and used in responding to the hypotheses.

Data Analysis

The data collected from the pre-test score was processed using descriptive statistics by comparing the mean scores of the two cohorts to establish whether individuals in the two cohorts have similar background knowledge and ability levels before applying the respective teaching approach on either group. The data gathered from the post-interventional test was processed using SPSS version16.0. Since the group involved in the study were made up of two different groups, two sets of performances were compared using t-test. The aim of using t-test was to determine whether there was a significance difference between the achievement scores of the two cohorts.

Results

A pre-test was conducted to determine whether there was no significant difference in the competent, background knowledge and ability levels of the individual students in the various groups that were used for the study before the interventions were applied. The mean scores obtained showed no significant difference between the ability levels of the two classes, and the assumption was that either the two approaches when applied on either of the classes would elicit substantial academic difference as postulated by Campbell and Stanley (1963).

Pre-test scores of students

The mean scores of the pre-test conducted for the two classes before introducing the treatments were compared using Descriptive statistics as shown in Table 1.

Table 1: **Descriptive statistics of pre-interventional scores**

GROUP A		***GROUP B***	
Mean	24.85	Mean	24.825
Median	24.5	Median	24.5
Mode	15	Mode	25
Standard Deviation	8.325278158	Standard Deviation	8.481919
Confidence Level (95.0%)	2.662553126	Confidence Level (95.0%)	2.712649

At the confidence level of 95.0%, the modal score for the two cohorts varied, the mean scores were almost the same (24.85 for Group A and 24.825 for Group B) (Table 1). This indicates that the two groups had similar conceptual understanding and there were no differences in the ability levels of the two groups. Values of standard deviation and the range for the two groups were also similar signifying no significant difference between the degrees of spread of the two set of scores. This implies that before administering the lessons with the two approaches, the learners had no significant differences in conceptual understanding of glycolysis and Krebs' cycles.

$H_0$1. Learning Cycle Approach (LCA) has no significant effect on students' achievement in the "Glycolysis and Krebs cycle" at the SHS level.

To respond to the Null hypothesis one (H_{01}), the pre- and post-test scores of the experimental group were subjected to t-test analysis of variance using SPSS version 18. The result is presented below;

DATA:

$D^2 = 133768$, $n = 40$, $D = 2660$, $\bar{D} = 56.6$

Calculating for t-value

$$t = \frac{\bar{D}}{SEo}, \quad \text{but } SEo = S/\sqrt{n}$$

Also,

$$S = \sqrt{\frac{\sum D^2 - \frac{\sum D^2}{n}}{n-1}}$$

$$\text{Therefore } S = \sqrt{\frac{133768 - \frac{2260^2}{40}}{40-1}}$$

$S = 12.4$

From $SEo = S/\sqrt{n}$, $\Rightarrow SEo = 12.4/6.3$

$\therefore SEo = 2$

$$\Rightarrow t = \frac{56.6}{2} = 28.25$$

From the t-test, one tail with alpha value of 0.05 and degree of freedom of 39, the tabulated t-value is 2.032 and the calculated t-value is 28.25. Since the tabulated t-value of 2.032 is lower than the calculated t-value of 28.25, it means there is a significant difference between the pre-test scores and the post-test scores of the experimental group. Therefore, the null hypothesis is rejected. This means, the LCA has a significant impact on the academic achievement of the Experimental group.

H_{02}. There is no significant difference between the academic performance of students who received instructions through the LCA and those who received instructions through the CTA.

The null hypothesis two (H_{02}) was tested using unpaired t-test in Microsoft Office Excel 2010 version as presented in Table 2.

Table 2: T-test analysis of the post-test scores of the Experimental and Control group

	GROUP A, POST-TEST SCORES	*GROUP B. POST TEST SCORES*
Mean	81.525	47.35
Variance	108.5121795	185.925641
Observations	40	40
df	73	
t Stat	12.59626306	
t Critical two-tail	1.992997126	

Table 2 presents the t-test analysis of the post-test scores of the Experimental and Control group. The mean score of the Experimental group is 81.5 whereas that of the Control group is 47.4. This suggests that the Experimental group performed far better than the control group. Therefore the LCA had a greater influence on students' academic achievement than the
CTA. Therefore, the null hypothesis is rejected.

Discussion

Findings from Table 2 shows that the LCA enhanced students' academic achievement better than the CTA since the mean scores of the Experimental group and the Control group was 81.5 and 47.4 respectively. This indicated that the use of the LCA enhanced students' conceptual understanding far better than the CTA. The significant difference between the mean scores of Group A and B justifies the assertion made by Lawson *et. al.,(*1989) when they concluded that the LCA can result in greater achievement in science, better retention of concepts, improved students' attitudes toward science and science learning, improved reasoning ability, and superior process skills than in the case of CTAs.

Differences between groups A and B may be attributed to many other reasons. For instance, the use of the Learning cycle in teaching glycolysis and Krebs cycle gives the learner more freedom to operate. LCA boaster students' eagerness to study the concepts presented, which yielded a good achievement scores than the Conventional approach, where teachers' always feed learners with information. The CTA restricts the learner from thinking without satisfying their academic curiosity. Due to poor achievement yield of the CTA, Hunter (1997) downgraded the use of Conventional teaching approach on the basis that it does not permit the learner to build the necessary intrapersonal connections that are essential for learning.

The LCA allows the learners to interact with their environment and among themselves. This also enhances their communication skills, critical thinking ability, able to criticize their works and accept criticism. Indeed, the 5E's of the Learning cycle develops all the learning faculties of the student. The 'Explore' stage of the Learning cycle motivates students to explore their immediate ambience so as to satisfy their curiosity by finding answers to their challenges with regard to the topics they studied. These benefits of the Learning cycle also expose the weaknesses in the Conventional teaching approach as indicated by Hunter, (1997).

In addition to the above reasons, it is noted that interaction among peers also reduces students' shyness and build their confidence levels. It positively influenced students' search for knowledge in glycolysis and the Krebs cycle.

Furthermore, the explain stage allowed the students to build connections between what they learnt and the new concept to be learnt without any fears. It also builds students self-efficacy in the learning of glycolysis and the Krebs cycle. The evaluation stage gave them the opportunity to reflect upon what they did and also made their own corrections without the teachers' intervention. Students easily overcome their perceived extraneous concept to acceptable alternate concept without difficulties. This means, that the Learning cycle approach enhances high retention rate as indicated by Lawson *et. al.*, (1989).

The higher achievement score of the Experimental group compared with the low achievement score of the Control group is in line with studies conducted by Lawson *et. al*. (1989).

Finally, the low achievement scores of the Control group is comparable to studies conducted by Johnson, Aragon, Shaik, and Palma-Rivas (2000), that CTA does not support student's academic satisfaction.

Conclusions

The aim of this study was to determine the impact of the LCA on SHS students' achievement in glycolysis and Krebs' cycle. The findings of the studies have revealed that the LCA developed by Karplus in 1967 improves academic achievement of students. It was again revealed that although the academic achievement of students is influenced by teaching approaches used by teachers, the CTA of teaching has marginal positive impact on students' academic achievement. Therefore, it should not be frequently used as teaching instruction, especially when teaching concepts perceived by students as difficult.

Recommendations

It is recommended that science teachers should embrace the use of the LCA as proposed by Rubba, (1992) and NRC, (1996). Teachers should use approaches that involve students as active learners and restricts teachers to the role of facilitation. Finally, any teaching approach adopted by science teachers should encourage interaction among learners and their environment rather than 'spoon feeding' learners with stuffs.

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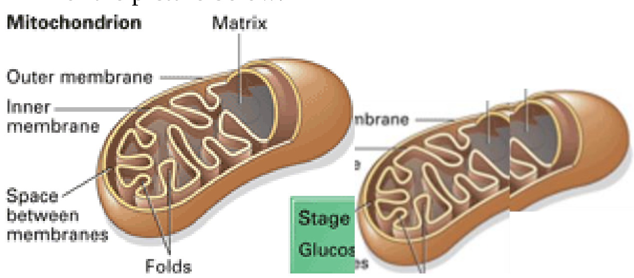
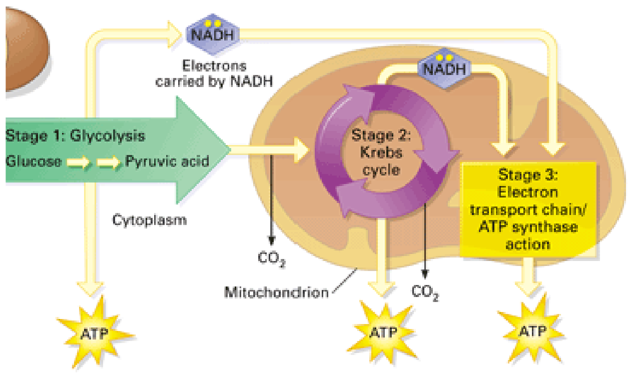
APPENDIX A: TEACHING HINTS ON TEACHING GLYCOLYSIS AND KREB CYCLE WITH LEARNING CYCLE

Stage	Stage That is *consistent* with the BSCS 5E What the teacher does	What students do
Engage	Piques students' curiosity and generates interest in cellular respiration by using riddles. E.g. Riddle, riddle, I am a parent with three children one of them is called electron transport; the second one is called glycolysis. Who is the third child and who am I? Determines students' current understanding of the **Structure of Mitochondria** by **Inviting** students to express what they think.	Become interested in and curious about the concept Express current understanding of the structure of Mitochondrion. Raise questions such as, What do I already know about Mitochondrion? What do I want to know about it? How could I find out?
Explores	Encourages student-to-student interaction by asking probing questions as you observe and listen to how they argue during their peer interactions. Asks probing questions to help students make sense of their experiences. Provides time for students to puzzle through problems Eg.1. What is the function of mitochondrion in cellular respiration, 2. in your own words, discuss the features of the picture below:  3. The first stage in cellular respiration is glycolysis: with reference to the picture below, discuss the main purpose of this stage, 4. Ask students in groups of three to 'Google' the terms " Glycolysis, Krebs cycle and electron transports and find their meanings from at least three links  	"Mess around" with materials and ideas Conduct investigations in which they observe, describe, and record data Try different ways to answer the given questions. Acquire a common set of experiences so they can compare results and ideas. Compare their ideas with those of others
Explain	Encourages students to use their common experiences and data from the Engage and Explore lessons (internet experience, literature search etc.) to develop explanations to how and why glycolysis occurs? Asks questions that help students express understanding and explanations. E.g. What is the name of that acid that is produced during glycolysis? Requests justification (evidence) for students'	Explain Glycolysis in their own words. Base their explanations on evidence acquired during previous investigations Record their ideas and

	explanations. Provides time for students to compare their ideas with those of others and perhaps to revise their thinking. Introduces terminology and alternative explanations after students express their ideas E.g. Meaning of metabolic pathway. A specific enzyme that catalysis (speeds up) each reaction in a metabolic pathway.	current understanding Reflect on and perhaps revise their ideas. Express their ideas using appropriate scientific language. Compare their ideas of Metabolic pathway with what scientists know and understand
Elaborate	Focuses students' attention on conceptual connections between new and former experiences. Encourages students to use what they have learned to explain how Krebs cycle and electron transport occur. Reinforces students' use of scientific terms and descriptions previously introduced. Asks questions that help students draw reasonable conclusions from evidence and data	Make conceptual connections between Krebs cycle and glycolysis Use what they have learned on Glycolysis to explain Krebs cycle. Use scientific terms and descriptions. Draw reasonable conclusions from evidence and data. Communicate their understanding to others
Evaluate	Observes and records as students demonstrate their understanding of Glycolysis and Krebs Cycle. Provides time for students to compare their ideas with those of others and perhaps to revise their thinking. Interviews students as a means of assessing their developing understanding. Encourages students to assess their own progress. Eg. Explain how the two main stages "Glycolysis and Krebs Cycle" occur and let them compare with their own answers.	Demonstrate what they understand about the Krebs cycle and glycolysis and how well they can link the two to cellular resporation. Compare their current thinking with that of others and perhaps revise their ideas. Assess their own progress by comparing their current understanding of Krebs cycle and glycolysis with their prior knowledge. Ask new questions that take them deeper into a concept or topic area

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APPENDIX B: HINTS ON THE USE OF CONVENTIONAL TEACHING APPROACH IN TEACHING GLYCOLYSIS AND KREBS CYCLE

	That is *inconsistent* with the BSCS 5E Instructional Model	What students do
Engage	Invites students to raise their own questions Introduces vocabulary Explains concepts Provides definitions and answers Provides closure Discourages students' ideas and questions	Ask for the "right" answer Offer the "right" answer Insist on answers or explanations Seek closure
Explores	Provides answers Proceeds too rapidly for students to make sense of their experiences Provides closure Tells students that they are wrong Gives information and facts that solve the problem Leads the students stepby-step to a solution	Let others do the thinking and exploring (passive involvement) Work quietly with little or no interaction with others (only appropriate when exploring ideas or feelings) Stop with one solution Demand or seek closure
Explain	Neglects to solicit students' Explanations,ignores data and information students gathered from previous lessons. Dismisses students' ideas and accepts explanations that are not supported by evidence. Introduces unrelated concepts or skills	Propose explanations from "thin air" with no relationship to-previous experiences. Bring up irrelevant experiences and examples. Accept explanations without justification. Ignore or dismiss other plausible explanations Propose explanations without evidence to support their ideas
Elaborate	Neglects to help students connect new and former experiences Provides definitive answers Condemns the students when they are wrong and leads them step-by step to a solution	Ignore previous information or evidence. Draw conclusions from "thin air" Use terminology inappropriately and without understanding
Evaluate	Tests vocabulary words, terms, and isolated facts Introduces new ideas or concepts Creates ambiguity Promotes open-ended discussion unrelated to the concept or skill	Disregard evidence or previously accepted explanations in drawing conclusions Offer only yes-or-no answers or memorized definitions or explanations as answers Fail to express satisfactory explanations in their own words Introduce new, irrelevant topics

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