

# Analogy-based Instructional Approach a Panacea to Students' Performance in Studying Deoxyribonucleic Acid (DNA) Concepts

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**Abstract:** The purpose of this study is to investigate the use of concept map to enhance academic performance of students in DNA concepts. Quasi experimental design was used for the study. Thirty-nine (39) students from Boakye Tromo Senior High/Technical School, Duayaw Nkwanta in the Brong Ahafo Region of Ghana were purposively selected and used for the study. Molecular Concept Achievement Test (MCAT) was developed, and used for both pre-test and post-test. The reliability coefficient of MCAT was established at 0.87 using Kuder-Richardson formula 20 (KR 20). All the thirty nine (39) students were taught the DNA concepts with conventional lecture-based instructional approach without any analogy for a period of two weeks and then tested to serve as pre-test. They were then exposed to the concepts again using analogy-based instructional approach such as “*building a house and bread baking analogies*” for another two weeks, tested at the end of the treatment period to serve as post-test. The null hypothesis was tested at  $p \leq 0.05$  levels using paired sample *t*-test together with Wilcoxon signed rank test. The study proved that there is a significant difference between the pretest and posttest mean scores of the students in favour of the post test ( $p < 0.01$ ). The students' performance was massively improved when taught with analogy-based instructional approach (treatment) compared to those taught with the conventional lecture-based instructional approach (prior to treatment) ( $t = -18.29, p < .001; Z = -5.53, d = 2.98$ ). It was then concluded from the findings that the analogy-based instructional approach of teaching and learning employed during the treatment processes improved the students' academic achievements, and lead to improvement in their performance of the DNA concepts.

**Keywords:** Academic Performance, DNA, Analogy-based Instructional Approach, Conventional Lecture-based Instructional Approach

## Introduction

There has been an excellent shift in emphasis on science teaching and learning over the years around the world. The shift concern in recent times is to own science classroom that is student-centered, activity-oriented and targeted on understanding instead of rote-learning and simple recall of knowledge (Owolabi, 2007). Biology is central or vital to science education. Biology concepts can sometimes be difficult, particularly when describing things that cannot be seen or abstract concepts that cannot be fully or absolutely apprehended for the first time (Chew, 2004). Some of the concepts taught in biology that students perceived difficult are evolution, ecology, physiology, genetics (such as DNA concepts), and molecular concepts in general (Nzelum, 2010; Okebukola, 2005; WAEC Examiner's Report, 2015).

Molecular concepts and for that matter molecular biology in general is one of the cornerstones of modern biology. The molecular aspects of biology became of central importance in the second half of the twentieth century, with the discovery of the Deoxyribonucleic acid (DNA) structure by Watson and Crick, an event that gave rise to entirely new disciplines (e.g., molecular genetics, genetic engineering) and influenced the course of many established ones (Cox & Nelson, 2000).

However, many teachers and students regard the molecular concepts and processes such as DNA concepts, and topics of molecular biology and genetics as very difficult, both to teach and to learn (Marbach-Ad, 2001; Templin & Fetters, 2002). Thus, grasping the dynamics of molecular phenomenon appears to be rather challenging for students in the context of life science. Students struggle to visualize

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the complexities underlying the most essential molecular and cellular processes. Reasons advanced for this difficulty in mastery of these biological concepts are poor handling of the concepts by the teachers, ineffective methods of teaching these concepts (teachers' failure to use effective teaching strategy), and lack of interest (Kimball, White, Milanowski & Borman, 2004).

A major challenge to biology educators is to teach these molecular processes concepts so that students can comprehend and understand their complexity. Explaining a biological event effectively is a cornerstone to success in biology, and curriculum policy documents reecho the significance of this ability (American Association for the Advancement of Science-[AAAS], 2009). Given the difficulties in molecular genetics (molecular biological processes and concepts) instruction, researchers who take a constructivist approach recommend enhancing the teaching of molecular genetics and concepts through educational methods that integrate modeling and visualization (Gilbert, 2003).

Visualization is defined as a simple process that creates a drawing, a diagram, or an image based on specific data or information. In fact, it is a cognitive process that produces a mental model in the human brain with the hope that this model supports better understanding or insight (Kerren, 2012). Biology is an inherently visual domain, perhaps more than in any other area of science. From an educational perspective, visualization helps us to grasp the complexity of biological events that are too small to see with the naked eye (or microscope in the case of biomolecules), or too rapid to experience with our own senses (Jenkinson & McGill, 2013). In other words visualization aids student understanding of complex processes because it assists in the conversion of an abstract concept into a specific visual object that can be mentally manipulated. There are various approaches to visualization in teaching and learning, including analogies (Chowdhury, 2015; Gabel, 2003; Genc, 2013), computer animations (Bukova-Güzel & Cantürk-Günhan, 2010; Daşdemir & Doymuş, 2012; Elmstrom, 2011), illustration and Graphics (Hibbing & Rankin-Erickson, 2003; Lih-Juan, 2000), slow motions (Ekici & Ekici, 2011; Hoban, Loughran & Nielsen, 2011) and concept maps (Ameyaw, 2015; Novak & Canas, 2008).

There are substantial body of literatures which report on the benefits of teaching with analogies and its success in science education. Analogy is a process of establishing similarities between a familiar concept (analogue) and a new concept (target) (Dilber & Duzgun, 2008). The target is what needs to be learnt. Analogies allow students to think about complex and

abstract subjects in simple or familiar terms. Abstract concepts are qualitatively different from their concrete counterparts; the abstract concept is often ambiguous, defined by symbolism rather than direct perception and the understanding of the abstract concept usually depend on the mastery of a substrate of underlying concepts. Use of an analogy provides a bridge to access the abstract concept. The learner first recalls the analogy; this then stimulates recall of what is known about the new concept by reconstructing the nature of the "is like" relationship represented in the analogy (Gulfidan & Bryan, 2003). Leach and Scott (2003) suggest that analogies are simplified models that can be used in science teaching and learning as they reinforce explanations and connect ideas to future learning. Effective analogies motivate students, clarify students' thinking, help them overcome misconceptions and help them visualize abstract concepts (Orgil & Thomas, 2007). There is a consensus in science education literature that use of analogical teaching approaches is a sure way of helping teachers and students to overcome difficulties associated with teaching and learning of difficult and abstract science concepts. For example, studies on using analogies in science classrooms have shown its positive impact on: achievement (Genc, 2013; Nwankwo & Madu, 2014), retention (Glynn & Takahashi, 1998), conceptual understanding (Gabel, 2003), conceptual change (Chiu & Lin, 2005), inferential reasoning (Yanowitz, 2001), thinking skills (Salih, 2010); and attitudes toward science (interest) (Coll, France & Taylor, 2005). Abstract and challenging concepts in biology can be understood if analogy is used to illustrate the points (Gongden, 2016).

It may therefore be concluded that analogies-based instructional approach, when coupled with lecture method have some useful implications and effects on teaching and learning of science and may effectively help to improve students' academic performance and retention of science process and content, particularly abstract ones. In spite of the effectiveness of these two instructional approaches in the teaching and learning of abstract and complex biological concepts, there has been little or no use of such instructional approaches in Ghana schools. Where they have been used sparingly, there seem to be little or no investigations been done into the effect of integration of such instructional approach for teaching and learning especially in biology teaching on student academic performance. In other words, it remains unclear and for that matter the gap to which this study sought to fill the extent to which analogy-based instructional approach influence biology students' academic performance in biological molecular processes and concepts especially in deoxyribonucleic acid (DNA) concepts such DNA

structure and replication, transcription and translation (protein synthesis) concepts. Again, there seems to be no literature on such study been documented in Tano North District and Ghana at large, a gap the present study sought to fulfill.

It is against this background that this study sought to investigate how Analogy-based instructional approach can be a panacea to students' performance in studying Deoxyribonucleic acid concepts, specifically, deoxyribonucleic acid (DNA) structure and replication, transcription and translation concepts at Boakye-Tromo Senior High/Technical School, Duayaw Nkwanta in the Tano North Municipal of the Brong Ahafo Region, Ghana.

The study was therefore guided by the following research hypothesis:

**H01:** The use of analogy-based instructional approach has no significant effect on students' performance in DNA concepts.

### Methodology

The research design for this study is quasi experimental research design. Quasi experimental research design is used when there is non-randomization of research subjects (Nworgu, 2006). This design was adopted because it was not possible for the researcher to randomly sample the subjects and assign them to groups. Hence, this design was very suitable for this study. The sample population was drawn from students reading biology as elective course in the Boakye Tromo Senior High Schools in the Tano North Municipal of the Brong Ahafo Region of Ghana through purposive sampling technique. A total sample of thirty nine (39) students comprising of seventeen (17) males and twenty two (22) females was purposively sampled and used for the study. All the thirty nine (39) students were taught the DNA concepts with conventional lecture-based instructional approach without any analogy for a period of two weeks and then tested to serve as pre-test. The students were then exposed to the DNA concepts again using analogy-based instructional approach such as "*building a house and bread baking analogies*" (see Appendix) for another two weeks, tested at the end of the second week which served as post-test.

Generally one instrument was used for data collection in this study that was Molecular Concept Achievement Test (MCAT). The Molecular Concept Achievement Test (MCAT) was made up of ten (10)

multiple choice test items, five (5) true or false items and five (5) fill-in the blanks. It based on the contents of the DNA structure and replication, RNA transcription and protein synthesis (translation) concepts taught, constructed eight (8) objective test items and drew twelve (12) from past West African Examination Council (WAEC) questions. All the five (5) true or false items and five (5) fill-in the blanks test items were constructed by the researchers. Though the same instrument (MCAT) was used for pre-test and post-test, the test items were reshuffled and printed in different coloured papers in each test administration to make them appear different at a glance and avoid the students cramming the questions.

The instrument was subjected to both face and content validity scrutiny by experts in the subject area. Piloting of the instrument was done at Bechem Presbyterian Senior High School and the reliability coefficient of the instrument was calculated to be 0.87 using Kuder-Richardson formula 20 (KR-20).

Mean, standard deviation, Cohen *d* effect size, box plot and paired sample *t*-test together with Wilcoxon signed rank test were used to analyse the extent to which the use of analogy-based instructional approach improve students' academic performance of DNA concepts. Paired sample *t*-test was used to compare the students' pre-test and post-test scores to establish whether there was a significant difference between the two test scores. Effect size was also estimated to determine the magnitude of improvement in the students' performance after the treatment. Again, boxplot was also used to give pictorial representation of the performance of the students in the pre-MCAT scores and post-MCPT scores.

### Results

To attest the extent to which the use of analogy-based instructional approach improves students' performance in DNA concepts, the mean, standard deviation, Cohen *d* effect size and paired samples *t*-test together with Wilcoxon Signed Ranked Test statistics were used to analyse the students' pre-intervention test (pre-MCAT) and post-intervention test (post-MCAT) scores (Table 1). Also, box plot (Figure 1) was used to give pictorial illustration of the performance of the students in both pre-MCAT and post-MCAT scores, which helped to judge the practical significance of the test scores.

**Table 1:** Comparison of Pre-test and Post-test Scores of Students taught with Analogy-based Instructional Approach (N=39)

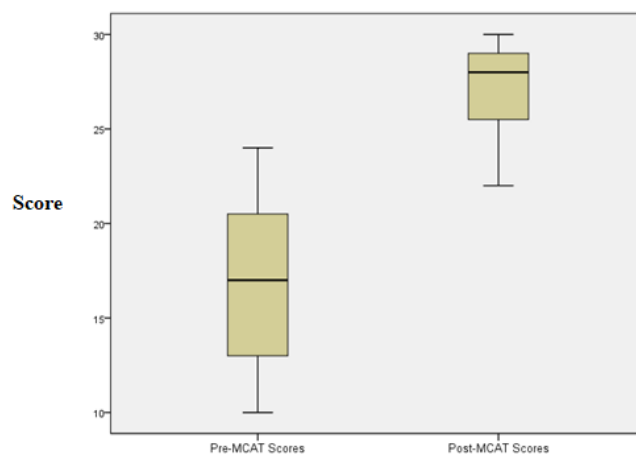
Paired Samples t-Test						
Test	...Mean	SD	df	t-cal	p-value	ES (Cohen d)...
Pre-test	16.62	4.37	38	-18.29	.000	2.98
Post-test	27.13	2.39				

Wilcoxon Signed Ranked Test						
Test	...Median	SD	df	Z-statistic	p-value	ES (Cohen d)...
Pre-test	17.00	4.37	38	-5.53	.000	2.98
Post-test	28.00	2.39				

Significance level,  $\alpha = 0.05$ , SD = Standard Deviation, ES = Effect Size

From the data presented in Table 1, the students' mean scores of the achievement test before and after the use of the analogy-based instructional approach were 16.62 (SD = 4.37) and 27.13 (SD = 2.39) respectively. It shows a mean gain (an increase) in the achievement test score from pre-test (prior to the intervention) to post-test (after the intervention). From the Table 1, it can be observed that the mean difference (mean gain score) between the pre-test and the post-test is 10.51. To find out if the mean difference of 10.51 was statistically significant, paired samples *t*-test together with Wilcoxon Signed Ranked Test statistics was conducted at 5% significant level. This revealed a statistically significant difference in the students' performance in the concepts of DNA structure and replication, transcription and translation ( $t(38) = -18.29, p < .001; Z = -5.53$ ). Low standard deviation scores show that students' scores clustered around the mean score. The higher mean achievement score and low standard deviation in the post-test score showed that most students in the analogy-based instructional group performed impressively better in the concepts of DNA than those taught with the conventional lecture-based instructional approach (prior to intervention). To know the magnitude of the effect of the analogy-based instructional approach on the students' performance, effect size was calculated using Cohen *d* effect size statistic ( $d = 2.98$ ). This shown that there was a large effect size, indicating that analogy-based instructional approach had positive and substantial effect on the students' performance after its intervention. Furthermore, the illustrations in the box plot (Figure 1) confirm the extent to which the students had improved in term of performance in DNA concepts upon using the analogy-based instructional approach.



Type of Test

**Figure 1:** Performance of Analogy-based Instructional Group in the Pre-test (Pre-MCAT) and Post-test (Post-MCAT) Scores

It can be seen from the illustration of the box plot (Figure 1) that the students improved massively in their performance and understanding of the DNA concepts on using the analogy-based instructional approach. Again, from Figure 1, the minimum score recorded in the pre-test (prior to intervention) was 10 while the maximum score was 24. As a result of the intervention, the minimum score the students obtained from the post-test (after the intervention) was 22, found to be twice the one obtained in the pre-test, almost equal to the maximum score of the pre-test. This implies that effective application of analogy-based instructional approach could greatly enhance students' academic performance in the DNA concepts and other biological molecular concepts in general.

#### Discussion

The findings of this study proved that there is a significant difference between the pre-test and post-

test mean scores of the students when analogy-based instruction applied at  $p < 0.01$ . The students' performance was massively improved when taught using analogy-based instructional approach (intervention) as compared to the conventional lecture-based instructional approach (prior to intervention). This implies that teaching with analogies has a positive effect on students' performance. Therefore, teaching with analogies is an effective method for higher learning achievement. The reason for the difference in the performance is not far fetch from the fact that analogy-based instructional approach allowed new concepts, especially abstract and complex concepts to be more easily assimilated with the student's prior knowledge by enabling them to develop a more scientific understanding of the concept. Teaching with analogies allows students to actively participate in the learning process. Analogies can help students relate new information to prior knowledge, to integrate information for one subject area into another, and to relate classroom information to everyday experiences. In this case, students were able to convert abstract knowledge into concrete knowledge, and therefore overcame alternative conceptions. This finding is in line with the findings of Ayanda, Abimbola and Ahmed (2012), Chiu and Lin (2005), Harrison & Jong (2005), Nawaf (2016), and Owolabi (2007). The finding of Ayanda, Abimbola and Ahmed (2012) on the use of analogies on the achievement of Senior School Biology Students at Oro in Kwara State of Nigeria indicated that the experimental group significantly performed better than the control group exposed to the conventional method. Similarly, Owolabi (2007) reported that teaching-with-analogy can clarify students doubt on specific information regarding scientific concepts, thus leading to better performance as compared to the lecture method. The finding of Harrison and Jong (2005) also emphasized that analogies support meaningful learning and help students to construct complicated and abstract concepts easily.

### Conclusion

The study proved that there is a significant difference between the pretest and posttest mean scores of the students ( $p < 0.01$ ). That is, the students' performance was massively improved when taught with analogy-based instructional approach (intervention) as compared to the conventional lecture-based instructional approach (prior to treatment) ( $t = -18.29$ ,  $p < .001$ ;  $Z = -5.53$ ,  $d = 2.98$ ). The study therefore concludes that analogy-based instructional approach is the best approach to use when teaching students the concepts of DNA because it has the higher potential of enhancing Senior High School students' academic performance in the DNA concepts.

### Recommendations

It is recommended that seminars and workshops should be organized by Educational Institutions to sensitize in-service biology teachers on the use of the analogy-based instructional approach in teaching and learning of biology, especially on abstract and molecular concepts such as DNA concepts. Again, teachers should select analogies that are familiar to students because such analogies would eliminate and prevent misconceptions, motivate students, avoid time wastage, and again, it easy to use by the teachers. They should also encourage and guide students to make or construct their own analogies because such analogies are more effective.

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APPENDIX

Example of the Analogies Used in the Teaching of DNA Concepts: Building a House and Bread Baking Analogies for DNA Concepts (Enriched Multiple Analogy)

<b>LIKE (WHERE THE ANALOGIES MATCHES THE CONCEPTS)</b>		
<b>Transcription and Translation Concepts</b>	<b>Building a House Analogy</b>	<b>Bread Baking Analogy</b>
DNA-the set of instructions for the cell	Master plan of a house (Building plan)	Cook book (Recipe) containing set of instruction for bread making
Gene-is the single DNA instruction	Is a single instruction/ step in the building plan	Is a single instruction/step in the cook book/recipe
Ribosome	Foreman/Contractor	Cook/chef
Cytoplasm	Construction site	Kitchen
Nucleus	Foreman's office at the site	Pantry (store room for keeping ingredients)
Amino acids	Blocks	Ingredients
Transcribing DNA to make message RNA (mRNA) (i.e. Transcription)	Making a copy of the master plan for use at the construction site	Making a copy of the recipe used at the kitchen
Messenger RNA (mRNA)	Photo copy of the master plan	Photo copy of the original recipe plan
The ribosome reads the mRNA one codon at a time	The Foreman reads the photo copied plan one step at a time	The chef reads the photo copied recipe one step at a time
Each codon correspond to a specific amino acid	Each step in the plan refers to a specific design/style	Each step in the plan refers to a specific ingredient
Amino acids are sent to ribosome by Transfer RNA by truck	Blocks and other materials are sent to the supervisor	Ingredients are sent to chef by kitchen hands or car (tRNA)
Ribosome joins amino acids to form proteins/polypeptide (i.e. Translation)	The Foreman follows the plan to lay/arrange the blocks to build a house	The chef mixes ingredients food or bread
Energy to bond amino acids to form proteins	Mortal to bond blocks together	.....
Protein	Finished building	Finished bread/food
The same kinds of amino acids can be arranged differently to build lots of different proteins	The same kinds of blocks can be arranged differently to build lots of different houses	The same ingredients can be mixed/combined differently to make different kinds of breads or food
Mutation	Mistakes made by block Foreman	Mistakes made by the chef
<b>LIMITATIONS/UNLIKE (WHERE THE ANALOGIES BREAKS DOWN)</b>		
<ul style="list-style-type: none"> <li>❖ Protein synthesis are sub microscopic whereas building a house and baking bread are not</li> <li>❖ Blocks and ingredients for making bread can be cut up whereas amino acids are always used in their entirety</li> <li>❖ A supervisor can make changes to a design or a chef can make changes to the cook instruction but in protein synthesis, no intention changes can be made</li> <li>❖ Proteins are naturally made by the body cells whereas bread baking/building a house is made/build by man</li> </ul>		