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COMPARING THE EFFECTS OF ANALOGY-BASED AND ANIMATION BASED INSTRUCTIONAL APPROACHES ON THE COGNITIVE ACHIEVEMENT OF SENIOR HIGH SCHOOL STUDENTS IN DEOXYRIBONUCLEIC ACID CONCEPTS

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A THESIS IN THE DEPARTMENT OF SCIENCE EDUCATION, FACULTY OF SCIENCE EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY (SCIENCE EDUCATION) DEGREE

SEPTEMBER, 2018

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DECLARATION

STUDENT'S DECLARATION

I, ISAAC KYERE, declare that this dissertation, with the exceptions of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted either in part or whole, for another degree elsewhere.

SIGNATURE: ………………………………

DATE: ………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with guidelines for supervision of thesis laid down by The University of Education, Winneba.

NAME OF SUPERVISOR: PROFESSOR YAW AMEYAW

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ACKNOWLEDGEMENTS

My first and foremost profound gratitude goes to the Almighty God for His directions and infallible grace to do and complete this research. I humbly acknowledge my supervisor, Prof. Yaw Ameyaw, who showed interest in my topic at the very beginning and helped me through it. His exceptional commitment, dedication and encouragement were the major factors that contributed to the accomplishment of this thesis. I would also like to express my sincere appreciation to the staff and students of Boakye Tromo Senior High/Technical School and Yamfo Anglican Senior School where the study took place. I am also indebted to the intellectual support of Mr. Osei Dwumfour Charles for his immense help throughout the work. My appreciation goes to my families, course mates, friends and love ones for their diverse efforts in making this study a success.

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DEDICATION

To my late father, Michael Kwaku Ayim and my dear wife, Christiana Kyere Dankwah

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GLOSSARY

[Operational Definition of Terms and Abbreviations]

- ***Molecular concepts***: they are concepts in biology that studies the composition, structure and interactions of cellular molecules such as nucleic acids (DNA and RNA) and proteins that carry out the biological processes essential for the cells functions and maintenance.
- ***Deoxyribonucleic acid (DNA)***: is a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms
- ***Replication***: is the process of making copies of DNA
- ***Transcription***: is the process that copies the message in a gene into a messenger ribonucleic acid (mRNA) molecule that will provide the instructions for making a protein molecule. That is, transcription process converts DNA into mRNA
- ***Translation***: is the process that converts (interprets or translates) mRNA into a string of amino acids (proteins). Messenger Ribonucleic Acid (mRNA) carries the genetic message from the nucleus to the ribosomes where proteins are synthesized.
- ***Instructional approach***: is the strategy a teacher may take to achieve objectives in teaching and learning process.
- ***Visualization***: is defined as simple instructional approaches that create a drawing, a diagram, or an image based on specific 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.
- ***Academic Performance***: Is the student's display of what is learned or skills acquired in school subjects, manifested through a test or examination scores.

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ABSTRACT

The principal focus of the study was to investigate the comparative effect of the extent to which analogy-based and animation-based instructional approaches influence senior high school students' cognitive achievement (academic performance and retention) in biological molecular concepts especially in deoxyribonucleic acid (DNA) structure and replication, transcription and translation concepts. Four research questions with two hypotheses guided the study and tested at 0.05 level of significance. A quasi-experimental design was used. A sample of seventy nine (79) second year Senior High School biology students were purposively sampled and used from two schools (Boakye Tromo Senior High/Technical School and Yamfo Anglican Senior High School) out of an estimated population of One Thousand and Fifty Eight (1058) biology students in the Tano North Municipal. DNA Concept Achievement Test (DNACAT) with a reliability coefficient of 0.88 was used to measure students' achievement and retention before and after treatments. Data obtained were analysed using various statistics including mean, standard deviation, Wilcoxon signed rank test, Mann-Whitney test, paired sampled *t*-test, independent sampled *t*-test, Cohen *d* effect size and one-way ANCOVA at a significant level of 0.05. Pictorially, box plots were used to present the data. The study indicated that both analogy-based and animation-based instructional approaches significantly improved the students' academic performance compared to the convectional lecture-based instructional approach. However, the study showed that the students taught with analogy-based instructional approach outperformed their counterparts who were taught with animation-based instructional approach especially in the application concepts/questions. Again, there was a significant difference in the retention of the concepts between the two instructional groups in favour of the analogy-based instructional group. Based on these findings, educational implications as well as recommendations and suggestions for further studies were made.

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CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter discusses the background to the study, statement of the problem, purpose and objectives of the study, research questions, and hypotheses, significance of the study, delimitation (scope) of the study and limitation to the study.

1.1 Background to the Study

Science education is an essential aspect of basic education that prepares children to stay in a world progressively defined by technological know-how and era (International Council for Science, 2002). 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. As indicated by Gbamanja (1991) in Ifeyinwa (2009), the study of biology involves exposing students to many opportunities which may facilitate them to comprehend different types of concepts, principles and theories. Biology is requirement to the study of medicine, pharmacy, agriculture among others. 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 replication, transcription and translation) and molecular concepts in general (Nzelum, 2010; Okebukola & Jegede, 1995; Okebukola, 2005; Oyedokun, 2002; WAEC Examiner's Report, 2016).

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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 and for that matter topic of molecular biology and genetics as very difficult, both to teach and to learn (Marbach-Ad, 2001; Templin & Fetters, 2002). Rotbain, Marbach-Ad and Stavy (2008) referring to these difficulties, argued that as the revolution in the field of molecular biology and genetics continue, the web of abstract concepts becomes increasingly complex. For example, students learn that an essential process such as ribonucleic acid (RNA) transcription involves RNA polymerase, but the fact that RNA polymerase itself is actually a multimeric protein complex is often not understood. Students also may not realize that RNA polymerase does not act alone, but rather that it is one component of the transcription process that involves several multiprotein complexes, and that each complex plays an essential role in the production of RNA. This one example exposes a shortcoming in curricular delivery (McClean, Johnson, Rogers, Daniels, Reber, Slator, Terpstra & White, 2005). Thus grasping the dynamics of molecular phenomenon appears to be rather challenging for students in the context of life science. Students struggle to visualize the complexities underlying the most essential molecular and cellular processes. A major challenge to biology educators is to teach these molecular processes concepts so that students can comprehend and understand their complexity.

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Explaining a biological event effectively is a cornerstone of success in biology, and curriculum policy documents reecho the significance of this ability (American Association for the Advancement of Science [AAAS], 2009). Molecular and cellular mechanisms and processes are notably difficult to explain in the classroom. When expounding natural phenomena, biologists describe mechanisms that regulate the behaviors of complex molecular and cellular systems, but explaining these mechanisms in the classroom presents a challenge, due to their complex, intangible, and abstract nature. This is due in part because mechanisms are characterized by a ramification and complexity of interactions between intangible molecular components that are often represented by abstract models of systems and language with heavy jargon (Tibell & Rundgren, 2010). There is an urgency therefore to make the molecular and cellular mechanisms explained by biologists more comprehensible to students (Caleb, 2016).

In the classroom, when instructors explain molecular and cellular mechanisms, they might ensure that students get practice, interpreting and generating their own explanations. One reason this could be difficult for students is that explanations regarding molecular systems are often entangled with everyday language and the way a scientist explains to a student may vary from the way he or she explains to another scientist (Tibell & Rundgren, 2010). Because of this, a teacher may deliver an explanation about molecular and cellular mechanisms that lacks some elements a biologist would use to explain such systems. Additionally, students tend to overestimate their ability to explain hidden and hierarchical processes (Rozenblit & Keil, 2002) so many students may have an illusion or a delusion of understanding molecular and cellular mechanisms. Furthermore, education research reports show that students, across many age groups, often construct explanations of molecular and cellular processes that differ from

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the explanations accepted by scientists (Abrams, Southerland & Cummins, 2001; Duncan & Reiser, 2007; Lewis & Kattman, 2004; Marbach-Ad, 2001).

Other 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; Maduabum, 1994). Teaching and learning are inseparable, because learning is a criterion and product of effective teaching. Teaching is a component of a whole that comprises the teacher, the learner, the content of the discipline, the teaching/learning process, and the evaluation of both the teacher and the learner. To encourage a deep approach to learning which leads to good learning outcomes, teachers should use an appropriate instructional strategy (Weng, 2003). Jibrin and Nuru (2007) identified poor methods of teaching as shortcomings or deficiencies of biology teachers. Many biology teachers prefer the lecture method of teaching and therefore shy away from innovative and activity-oriented teaching methods. It is teacher-centered and students are mostly passive listeners (Nwagbo, 1999; Nwosu, 1998; Okoli, 2006). These days, the old chalk and talk methods in front of a blackboard, or even the more updated whiteboard, marker and projector, are simply not enough for effective teaching and learning. As Abbas (2012) comments, students are tired of this teacher-centered model and complain that the class is very boring and monotonous and they want something new and different. On the performance of biology students, Bichi (2002) and Usman (2010) have observed that the lecture method promotes rote-learning without aiding understanding, thereby resulting in poor academic performance in evolution and genetic biological concepts.

Though the old methods may still be present, increasingly there is a demand for a more competitive instructional approaches and tools which will supply the needs of the students

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more effectively. This involves changes in both the instructional strategy and also the teaching and learning environment (Vonganusith & Pagram, 2008). 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).

Because of these challenges, many instructors no longer simply lecture in class and assign readings from principal textbooks. Most are looking for new approaches that improve student learning of abstract and biological processes. Some teaching methods and approaches have been proven to be efficient and productive in the teaching and learning of these abstract and difficult biological molecular processes/concepts and other science concepts than the conventional lecture method including; Dramatization, Concept Mapping, Project-based learning, Collaborative, Cooperative, Guided Inquiry and visualization methods, among others (Ajaja, 2013; Hmelo-Silver, Duncan & Chinn, 2007; Johnson & Johnson, 2008; McClean *et al*., 2005; Nwagbo & Okoro, 2012; Obomanu, Nwanekezi & Ekineh, 2014; Ogbu, 2010). The use of visualization is significant among these approaches (McClean *et al*., 2005). 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

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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; Yerrick, Doster, Nugent, Parke, & Crawely, 2003), computer animations (Bukova-Güzel & Cantürk-Günhan, 2010; Çelik, 2007; Daşdemir, 2006; Daşdemir & Doymuş, 2012; Elmstrom, 2011; Gil & Paiva, 2006; Gökhan, 2011; Iskander & Curtis, 2005; Kauffman, 2003; Powell, Aeby & Carpenter, 2003; Santos, 2009), illustration and Graphics (Hibbing & Rankin-Erickson, 2003; Lih-Juan, 2000), slow motions (Ekici & Ekici, 2011; Hoban, Loughran & Nielsen, 2011; McKnight, Hoban & Nielsen, 2011; Vratulis, Clarke, Hoban & Erickson, 2011) and concept maps (Ameyaw, 2015; Anderson-Inman & Zeitz, 1993; Anderson-Inman & Horney, 1996; Anderson-Inman & Diston, 1999; Aykanat, Doğru, & Kalender, 2005; Novak & Canas, 2008). For instance, Novak & Canas (2008) stated that concept mapping is a visual organizer that helps students represents a topic or concept by showing its relationships.

Learning is best achieved when a lecture is coupled with an animation (Paivio, 1990 cited in Bhatti, Shaikh, Rehman, Memon, & Buleidi, 2015) or analogy (Orgil & Thomas, 2007), because these combinations provide a reference from which students can appreciate the knowledge presented. There are substantial body of literatures which report on the benefits of teaching with analogies or animations and their 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; Newby, Ertmer & Stepich, 1995). 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 (Baker & Lawson, 1995; Genc, 2013; Nwankwo & Madu, 2014), retention (Glynn & Takahashi, 1998), conceptual understanding (Gabel, 2003), conceptual change (Chiu & Lin, 2005; Pittman, 1999), inferential reasoning (Donelly & McDaniel, 1993; Yanowitz, 2001), thinking skills (Salih, 2010); and attitudes toward science (interest) (Baker & Lawson, 1995; Coll, France & Taylor, 2005; Paris & Glynn, 2004). Abstract and challenging concepts in biology can be understood if analogy is used to illustrate the points (Gongden, 2016).

Animation on the other hand, refers to a simulated motion picture depicting movement of drawn (or simulated) objects or moving something that cannot move by itself (Mayer & Moreno, 2002). According to Lowe (2003), animation is a dynamic (pictorial) representation that can be used to make change and complex processes explicit to the learner. According to Thomas and Israel (2014), animation teaching is a device that has the features of both audio and visual representations that are used in the teaching and learning process for effective

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dissemination of knowledge. Animations are typically used by a teacher as a lecture supplement in the classroom or by students as individual learning tools. Learning research has demonstrated that visualising processes in three dimensions aids learning, and animations are effective visualisation tools for novice learners and aid in long-term memory retention (McClean *et al.*, 2005). Researchers and educationists affirm that animations significantly improved student learning (Akpinar & Ergin, 2008; Ardac & Akaygün, 2004; Ayotola & Abiodun, 2010; Ching, Ke, Lin & Dwyer, 2005; Ebenezer, 2001; Kraidy, 2002; Mayer 2003; Mayer & Anderson, 1991; Mayer & Moreno, 2002; Rieber, 1994; Sancar & Greenbowe, 2000; Weiss, Knowlton & Morrison, 2002).

It may therefore be concluded that both analogies-based and animation-based instructional approaches, 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 and increasing availability of animation as part of textbook packages and analogies used in some textbooks, 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 approaches for teaching and learning especially in biology teaching less alone their comparative study on student academic performance and retention. In other words, it remains unclear and for that matter the gap to which this study sought to fill the comparative study of the extent to which each of analogy-based and animation-based instructional approaches influence biology students' academic performance and retention in biological molecular processes and concepts especially in deoxyribonucleic acid (DNA) concepts such

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

It is against this background that this study sought to investigate the comparative effects of analogy-based and animation-based instructional approaches on second year biology students' academic performance and retention on deoxyribonucleic acid (DNA) concepts, specifically, deoxyribonucleic acid (DNA) structure and replication, transcription and translation concepts in the Tano North Municipal of the Brong Ahafo Region, Ghana.

1.2 Statement of the Problem

Over the years it has been observed that students in the Tano North Municipal do not perform well in biology examination, both internally and externally and in most cases find it difficult in answering questions related to DNA concepts. Among these, Boakye Tromo Senior High/Technical School and Yamfo Anglican Senior High School were the worst performing schools as observed in their Science and Maths Quiz performance over the years by the researcher who was also the Science and Maths Quiz Coordinator in one of the schools. Moreover, the assessment of WASSCE results in the schools within the Municipality from 2014-2017 indicates that only 28% and 38% for 2014; 31% and 38% for 2015; 41% and 40% for 2016 and 38% and 38% for 2017 from Boakye Tromo SHTS and Yamfo Anglican SHS respectively qualified for tertiary institutions (grades between A1-C6) (Appendix A). These observations were affirmed conservatively by West African Examinations Council's Reports, which stated that students' do not pass well in biology at the West African Senior School Certificate Examination (WASSCE) because of their inability to understand, retain and

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answer some biological concepts such as DNA and other molecular concepts which seem to be complex, difficult and abstract in nature (WAEC, 2013; WAEC, 2014; WAEC, 2015; WAEC, 2016; WAEC, 2017). Again, other factor of the report in relation to students' poor performance in the subject is the ineffective teaching approaches used by some biology teachers. But some instructional approaches have proven to be efficacious in the teaching and learning of these abstract and complex biological concepts and science in general than the dominated conventional lecture-based instructional approaches.

This study therefore sought to examine how well analogy-based and animation-based instructional approaches could improve teaching and learning (students' academic performance and retention) of molecular concepts, especially DNA concepts in the Tano North Municipal of Brong Ahafo Region.

1.3 Purpose of the Study

The purpose of the study was to investigate the effects of analogy-based and animation-based instructional approaches on biology students' cognitive achievement (academic performance and retention) in DNA concepts.

1.4 Objectives of the Study

The objectives of the study were to:

1. determine the extent to which the use of analogy-based instructional approach improves students' performance in DNA concepts.
2. ascertain the extent to which the use of animation-based instructional approach improves students' performance in DNA concepts.

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3. examine the differences in performance between the students in analogy-based and animation-based instructional groups in DNA concepts.
4. evaluate the differences in retention between the students in analogy-based and animation-based instructional groups in DNA concepts.

1.5 Research Questions

In the light of the specific objectives outlined above, the following research questions were considered:

1. To what extent does the use of analogy-based instructional approach improve students' performance in DNA concepts?
2. To what extent does the use of animation-based instructional approach improve students' performance in DNA concepts?
3. What differences exist in performance between the students in analogy-based and animation-based instructional groups in DNA concepts?
4. What differences exist in retention between the students in analogy-based and animation-based instructional groups in DNA concepts?

1.6 Research Hypotheses

The following research hypotheses were formulated and tested at 0.05 of significance.

1.6.1 Null Hypothesis

H_{01}: There is no statistical significant difference in the mean performance scores of students taught DNA concepts using analogy-based and animation-based instructional approaches.

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H_{02}: There is no statistical significant difference in the mean retention scores of students taught DNA concepts using analogy-based and animation-based instructional approaches.

1.6.2 Alternative Hypothesis

H_{01}: There is a statistical significant difference in the mean performance scores of students taught DNA concepts using analogy-based and animation-based instructional approaches.

H_{02}: There is a statistical significant difference in the mean retention scores of students taught DNA concepts using analogy-based and animation-based instructional approaches.

1.7 Significance of the Study

The findings of this study is hoped to be beneficial to the following groups of people: Curriculum planners, Ministry of Education and professional bodies like Ghana Association of Science Teachers (GAST), classroom teachers, students and researchers.

- The findings of this study would be relevant to curriculum planners. The findings of this study could make curriculum planners include analogy-based and animation-based instructional strategies in the teachers' guide for teaching DNA concepts in biology and other science subjects, mathematics and technology subjects if both equally found to improve achievement, retention ability and arouse and sustain interest of students in molecular concepts. They could include analogy and animation as alternative approaches which can be used in teaching abstract and difficult concepts in all science and its related subjects.

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- The Ministry of Education and professional bodies like GAST would benefit from this study. The Ministry of education alone or in conjunction with professional bodies like GAST would hopefully benefit by considering the findings of this study in developing instructional methods. They could organise academic conferences, workshops and seminars so as to communicate to science, technology and mathematics teachers in general and biology teachers in particular the alternative strategy which can be used to teach DNA concepts in particular and other abstract biology concepts and science subjects in general. The government could sponsor more research works on use of analogy and animation in sciences, mathematics and technology subjects.
- The study findings could be useful to classroom teachers who decide what instructional approach to use to present biological molecular concepts especially the DNA concepts. Results of this study if found valuable, could provide a guide for choosing analogy-based and animation-based instructional approaches as innovative instructional approaches for teaching DNA concepts and other abstract molecular concepts in biology and science in general.
- It is expected that the findings would be of immense benefit to the students. It will make DNA concepts like DNA structure and replication, transcription and translation concepts to be simplified in such a way that it will no longer be abstract and difficult for the students to understand. This will in turn help the students to understand other biology concepts that are related to these concepts and will improve students' achievement, interest and retention in biology.
- Biology teacher trainers in colleges of education and universities would also benefit from this study. The instructional approaches which they use in teaching biology students at that level could be enriched with analogy-based and animation-based

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instructional approaches as alternative approaches of inculcating DNA concepts and other molecular concepts. The biology student teachers if well prepared would use the strategies in teaching biology concepts by the time they graduate from school.

- Moreover there seems to be no literature in Ghana dealing with the comparative effect of analogy-based and animation-based instructional approaches on students' achievement and retention in DNA concepts particularly in DNA structure and replication, transcription and translation concepts. This would provide empirical research information in this regard. Thus this study would be a spring board for future researchers who might wish to embark on a similar study in biology and other discipline.

1.8 Delimitations of the Study

Delimitations are those characteristics selected by the researcher to limit the scope and define the boundaries of the study (Simon, 2011).

This research investigated the effects of analogy-based and animation-based instructional approaches on students' performance and retention in DNA concepts. The geographical scope of this study was restricted to Boakye-Tromo Senior High/Technical School, Duayaw Nkwanta and Yamfo Anglican Senior High School in the Tano North Municipal of Brong Ahafo Region. Second year general science biology students were used for this study because they are a stable year group, unlike first year students' who were not fully settles for their studies, or third year biology students who were facing their final year examination. The DNA concepts used in this study were DNA structure and replication, transcription and translation (protein synthesis) concepts in senior high school biology syllabus.

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1.9 Limitations

This study has some limitations that include the following:

1. The use of only second year senior high school biology students, purposively sampled from only two senior high school may limit the scope of generalization.
2. In this study, only DNA concepts unit from biology syllabus were used which may affect the generalization of the findings.
3. There was limited time for the study. Poor performance of students in biology is national issue and calls for nationwide investigation, however it was not possible for the researcher to do so due to limited time frame (within one academic year) to complete the study.

Despite these limitations, the findings were significant particularly in the use of analogy-based and animation-based instructional approaches to enhance students' learning of DNA structure and replication, transcription and translation (protein synthesis) concepts.

1.10 Organization of the Study

This research work is structured into five chapters. The first chapter is the introduction. The chapter is divided into sub- sections as the background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, research hypotheses, delimitation of the study, limitation of the study, definition of terms and organization of the study.

The second chapter deals with the literature review. It contains the theoretical framework of the study and conceptual framework basis of the study.

Chapter three of the study deals with the methodology used to solicit information for the study. It entails research design, population, sample and sampling technique, instrument, validity and

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reliability of the instrument, data collection procedure and data analysis. Chapter four deals with analysis, results and discussions of the study findings. Chapter five which is the last chapter of the study summarizes the study, draws conclusion, makes recommendations and provides suggestions for further research study.

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CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Overview

This chapter reviews the relevant literature for the study. It is carried out on three broad themes, each with sub-headings:

Theoretical Framework

- Constructivism Theory for Analogy-based Instruction
- Dual Coding Theory and Cognitive Theory of Multimedia Learning for Animation-based Instruction

Conceptual Framework

- Importance and Challenges in Teaching Biological Molecular Processes and Concepts such as DNA and Genetics
- Instructional Delivery Approaches
- Concept of Analogy-based Instruction and Science Teaching
- Concept of Animation-based Instruction and Science Teaching
- Students' Academic Performance in Biology in Ghana
- Concept of Student's Retention Ability

Empirical Studies

- Empirical Studies on Analogy-based Instruction
- Empirical Studies on Animation-based Instruction
- Summary of the Literature Reviewed and the Implication on the Present Study

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2.1 Theoretical Framework

The theoretical framework for this study was based on two learning theories. These are the constructivism theory for analogy-based instruction and dual coding theory in line with cognitive theory of multimedia learning for animation-based instruction.

2.1.1 Constructivism Theory for Analogy-based Instruction

The theoretical basis that is guiding the present study on the use of analogy-based instructional approach to teach biological molecular processes and concepts is the constructivism theory of learning. The theory of constructivism is generally attributed to Bruner (1960) and Piaget (1980), who articulated that knowledge is internalized by learners through the processes of assimilation and accommodation. This implies that when individuals assimilate, they incorporate the new experience into an already existing framework without changing that framework. Constructivism is a fundamental theory that encourages learners to build ideas based on prior knowledge drawn from experience and social reality as they make sense of new knowledge (Vygotsky, 1978). According to Harrison (2001), constructivism is the process in which learners compare new information with old, within the context of their current conceptual framework and so reconstruct their knowledge. Ogunkunle and Gbamanja (2006) view constructivism as a process where learners actively take knowledge, connect it to previously assimilated knowledge and make it theirs by constructing their own interpretation. Ideally, analogy can help students to build meaningful relations between what they already know and what they are setting out to learn. In general, this activity of building relations plays a critical role in constructivist views of learning science, thereby involving students in the construction of knowledge and the creation of new ideas from what they already know (Yager, 1995). Carey (1986) suggests that prior knowledge has a useful consequence in learning. As

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learners learn, they manipulate themselves within the new context from our prior knowledge. Prior knowledge is the concept required for further knowledge. Knowledge is constructed by individual learners by interaction within the activity among users, technology and environment which is all within a context. Chiu and Lin (2005) suggest that no two events, experiences, or phenomena are same. To learn novel things, it is necessary to find similarities between things that are different and then create a bridge between them. However, when a known concept is compared with a new concept and creates a relation to conceptualize the new, it is referred to as "Analogy". Analogy makes the thing happen. In addition, analogy makes interactions more effective with the learner and the environment.

2.1.2 Dual Coding Theory and Cognitive Theory of Multimedia Learning for Animation-based Instruction

The importance and value of animation-based instruction seems to be associated with Paivio's (1986) dual coding theory in association with Mayer's (2001) cognitive theory of multimedia learning. Paivio's dual coding theory explains that human processes information in two different systems: a visual system that processes visual knowledge and a verbal system for processing verbal knowledge. Although they are independent, they are interconnected when the brain encodes, organizes, stores, and retrieves information. The dual coding theory states that learning is enhanced when information is coded both verbally and visually (Zhu & Grabowski, 2005). When students view and interpret graphics (such as animation) pertaining to the content they are learning, it codes visually, enhancing their verbal knowledge from the teacher's lecture (thus narration).

Mayer's (2001) cognitive theory of multimedia learning, proposed that students are able to create a deeper understanding of words when they establish connections between words and

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pictures than from words or pictures alone. Mayer's (2001) theory regards the learner as a constructor of his or her own knowledge, actively selecting, organizing, and integrating relevant visual and verbal information. This theory further claims that information should be presented in such a way that the learners' limited working memory resources are employed as efficiently as possible. This is especially the case with multimedia instruction, where students have to integrate different information sources like text, pictures, and spoken words. The theory provides useful insights into why different combinations of media can have different effects on comprehension and learning. Mayer focuses on the auditory/verbal channel and visual/pictorial channel, and defines multimedia as the presentation of material using both words and pictures.

Mayer (2001) proposed a cognitive theory model in order to explain the effects of multimedia materials on learning through: (i) dual channel assumption where the learner processes visual and auditory information through separate channels; (ii) limited capacity where learner's working memory is limited but can process each channel at a time; (iii) active processing where learning is integrated as compound information. Mayer's cognitive theory is illustrated in Figure 1.

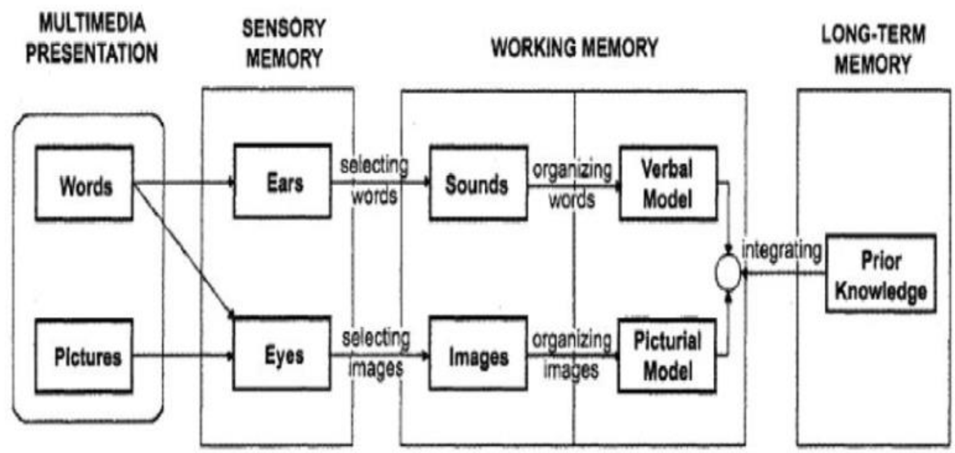

Figure 1: Illustration of Mayer's Cognitive Theory of Multimedia Learning

Source: Mayer, 2001.

Paivio's (1986) dual-coding theory and Mayer's (2001) cognitive theory of multimedia learning therefore provide the theoretical framework for animation-based instruction approach used in this study and based on that focused on combination of word such as on-screen text or spoken/narration word and dynamic picture (animation).

2.2 Importance and Challenges in Teaching Molecular Biological Processes and Concepts such as DNA and Genetics

The importance of understanding molecular biology and genetics is essential for our students. Some of our students will go on to become doctors, pharmacists, biochemists, and drug developers with the potential to make significant gains in developing new drugs, medical diagnostics, treatments, improvements in food production, as well as improvements in forensic techniques. The fundamental understanding of the structure of DNA and the processes associated with it such as replication, transcription and translation (protein synthesis) will be critical for students to understand in order to tackle these tasks (Christine,

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2013). As Tibell and Rundgren (2010) state, the rapid progress and potential application of cellular and molecular life science have profound implications, not only on our scientific understanding, but also on our future health and prosperity. The majority of our students will not pursue this field, though their understanding will be equally important. Cellular and molecular biology, more specifically DNA and genetics research particularly related to biomedical issues, raises a host of important political, economic, and ethical issues. Members of our society must receive a functional understanding of these topics to fully appreciate the questions and answers that these field raises (Marbach-Ad, 2001). It wouldn't be a far jump to assume that the future of human prosperity partially rests on our students' ability to understand how others manipulate DNA and its processes such as replication, transcription and translation (protein synthesis) as well as the cellular functions (processes) that are interdependent on DNA and molecular processes. Research indicates that cellular and molecular biological processes such as cell division, DNA structure and replication, transcription and translation (protein synthesis) and other genetics concepts are difficult units in biology for students to truly understand. What makes cellular and molecular biological processes and concepts such as DNA and genetics teaching and learning so challenging?

One of the most common barriers cited in teaching and learning such concepts is the complexity and abstract nature of it. Understanding basic biological processes such as DNA replication, transcription and translation processes is very difficult because they occur in three-dimensional space with many events occurring simultaneously (Guzman & Bartlett, 2012). Additionally, these processes are part of complex systems that have several different levels of organization. Scientific phenomena, more specifically biochemical processes are investigated within the macroscopic, microscopic, and mostly in the submicroscopic levels of organization (Schonborn & Anderson, 2006). For example, a process such as protein synthesis

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(translation) starts at a macroscopic level by discussing the purpose of the process in an organism. It then gets discussed at a microscopic level when students learn what structures these processes take place in. When the actual mechanism is being taught, students are learning at the molecular level. In order for students to completely understand these processes, they have to be able to translate between these three levels of organization.

Another common barrier cited when teaching molecular biological concepts is the use of domain-specific language. There are many misconceptions that stem from the misunderstanding of certain terms. For example, one study found that students often used the term gene, genetic information, and chromosome interchangeably with little use at all of the word allele (Lewis & Kattmann, 2004). How can students understand the central dogma of biology if they cannot understand the terminology used to explain it? The challenge with domain-specific terminology is twofold.

- The first challenge is the complexity of scientific jargon. Scientific terms are often abbreviated into acronyms to help facilitate communication among professionals. In the process though, this often confuses lay people, losing them in translation. In molecular biology, one could make an argument that more acronyms are used for molecules instead of full names. DNA is used to shorten deoxyribose nucleic acid, mRNA for messenger-ribose nucleic acid, tRNA to abbreviate transfer-ribose nucleic acid, as well as twenty different three letter abbreviations for twenty different amino acids!
- The second challenge lies in the rapidly changing nature of science. As molecular biology related studies continue to develop rapidly, the meaning of related terms change as new knowledge is generated. The meaning of the word "gene" alone has changed drastically in the last one hundred years with the discovery of introns,

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overlapping genes, transposons, making a firm and enduring definition difficult to establish (Tibell & Rundgren, 2010).

Maduabum (1994) also identified teachers' failure to use effective teaching approach that would make the learning of molecular and cellular mechanisms concepts easier as another barrier to teaching and learning of processes/concepts. As such, there is a need for life science educators to address molecular and cellular concepts during instruction in a way that is sensitive to the documented difficulties so that students develop expertise to understand, interpret, evaluate, and generate explanations as biologist do and the best way to achieve this is through appropriate and effective instructional approach of which the present study sought to find out the extent to which analogy based and animation based instructional approaches can help improve teaching and learning of these concepts especially DNA structure and replication, RNA transcription and translation (protein synthesis) concepts.

2.3 Instructional Delivery Approach

Instructional delivery approach is a process in which a teacher uses variety of teaching approaches to communicate and interact with students around academic content. The teacher effectively engages students in learning by using a variety of instructional delivery approaches in order to meet individual learning needs. According to Bannon (2012), instructional delivery approach is a way in which information is presented to students. It is also an educational approach for turning knowledge into learning. Researchers like Atadoga and Lakpini (2013), Lawal (2007), Usman (2010) found that the persistent low academic achievement in science education is attributed to teacher instructional approaches among others. Thus, instructional approaches used by teachers in teaching-learning process have significant influence on learners' academic achievement, retention and interest in the concept. Berlongieri (2013)

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states that teacher should use a variety of instructional approach to encourage students' development of critical thinking, problem solving and performance skills. This is because, students learn on different levels. Therefore, the way in which the instruction is given can help students use various types of skills to think and solve problems on their own. According to Etukudo (2006), the fall in standard of achievement in biology is incontrovertibly attributed to poor instructional delivery strategy adopted by teachers in schools. To support this assertion, Salau (2002) submitted that many researchers have adduced that low achievement and retention level in students' outcome both in internal and external examinations is traceable to poor instructional delivery approaches adopted by teachers. This implies that the mastery of biology concept might not be fully achieved without the use of a good instructional delivery approach. West African Examination Council (WAEC) Chief Examiner's reports (2013-2016) state that the persistent poor performance of students in biology at West African Senior Schools Certificate Examination (WASSCE) leaves one in doubt about the effectiveness of instructional materials and delivery approaches popularly used by biology teachers for the teaching and learning of biology.

The prevailing teaching method in Ghana is the lecture teaching method in the guise of conventional teaching method. Conventional teaching method indicates a method that is formal and has been in use for long. Convectional teaching method is usually nicknamed by teachers as traditional teaching methods (Okeke, 2011). Convectional teaching method can be defined as an oral presentation given to a class by a teacher. It involves talk and chalk as well as labs which involves using demonstration to teach students. Sometimes questions and answers may be included, showing of teaching aids and practical may be involved in convectional teaching method. Convectional teaching method is the prevailing method of disseminating knowledge at virtually all levels of academics in Nigeria for many years

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(Geraldine, 2000). The situation seems not different in Ghanaian education. Teachers are often comfortable with the traditional lecture methods because it enables them to remain in control of content and time. Traditional lecture methods can also be very linear in scope and sequence. Most textbooks provide charts outlining the entire academic course so that teachers know the direction of learning. Other advantages of the traditional lecture method are the usefulness in introducing new materials, utilization in conjunction with other teaching techniques, and its efficiency for presenting to large groups as well as content areas containing many facts. Science teachers use mostly the lecture method for imparting information (Geraldine, 2000). However, the traditional lecture method has had limited success in meeting the fast paced, high quality demands of today's learning environment (Geraldine, 2000). Cepni, Tas and Kose (2006) states that, the use of traditional instructional approach to teach biology makes students understand subject at knowledge level and they usually memorize the science concepts without understanding the real meanings. This instructional method, according to scholars, is mainly authoritarian in nature. Other distinct disadvantages associated with traditional instructional methods include student boredom, difficulty in accounting for individual learning differences, the prerequisite of advanced speaking skills of the teacher, and the difficulty of producing learning transfer to new situations. Additional problems include one-way communication (teacher to students), lack of enthusiasm and student involvement, lack of motivation for extra or advanced learning, and lack of development of concepts and other aids leading to true understanding. Under the traditional lecture method, the teacher, simply becomes only the expositor and drillmaster while the learner remains the listener and a storehouse of facts that can be retrieved by the teacher when needed (Usman, 2010). Research indicates that attention tends to lapse some 10 to 18 minutes into the lecture. Teaching strategies which can help the development of logical reasoning, critical skills and processes

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through scientific approach, are conspicuously lacking and they do not conceptualize science well as intended. This results in poor performance by the students. Therefore, the traditional lecture method is not effective for teaching and learning scientific concepts and it is obvious that alternative instructional delivery approach is needed to teach these sort of difficult and abstract concepts in biology. To support this assertion, the Educational Encyclopedia (2013) submitted that improvement of instruction has been a goal of educators as far back as the teachings of the Greek Philosophers Socrates. Nafees, Farouq and Tahirkheli (2012) are of the opinion that, the selection of proper instructional delivery approach ensures the achievement of the stated instructional objectives effectively. Appropriate instructional delivery approach portrays good teaching technique and successful learning. An instructional delivery approach is characterized by certain regularities in the ways in which teachers and students interact with each other and with instructional materials (Corcoran & Silander, 2009). According to Nafees, Farouq, and Tahirkheli (2012), instructional delivery approaches are used in the presentation of lesson to help the students learn by ensuring the smooth delivery of the instruction. Therefore, the classroom teacher must determine the most effective instructional delivery approach for his/her students on specific concepts. Among instructional delivery approaches use by teachers in delivering instructions are lecture, demonstration, discussion, brainstorming, peer instruction, problem solving, role playing, field trips, projects, simulations and so on. The search for improved approaches as an alternative to conventional lecture teaching method for teaching and learning of science especially the abstract concepts like genetics, cell division, DNA structure and replication, RNA transcription and translation (protein synthesis) is a continuous process (Geraldine, 2000). In the present study, the researcher investigated the effect of analogy-based and animation-based instructional approaches on Senior High Schools biology students' academic performance and retention in

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molecular biological concepts, especially DNA structure and replication, transcription and translation (protein synthesis) in the Tano North Municipal.

2.4 Concept of Analogy-based Instruction in Science

An epistemological difficulty that many students face with a considerable number of scientific concepts and biology in particular is the high level of abstractness associated with these concepts (Al-Balushi, 2011; Harrison & Treagust, 2000; Şekercioğlu & Kocakülah, 2008). This is because some of the difficulty experienced by students in these topics no doubt stem from lack of insight in the internal workings as well as inter and intra-phenomenal interactions that result in the observable outcomes (Ijioma & Onwukwe, 2011). The high level of spatial relations involved in some of these abstract entities and phenomena makes some low spatial ability students deny the existence of these entities and phenomena (Al-Balushi, 2011). Therefore, this high level of abstractness needs to be loosened so that students become able to visualise what scientists mean by the models they construct to make us better understand and predict the world around us. One way to do so is using pedagogical analogical models (Harrison & Treagust, 2000), or what are commonly known as analogies. Analogies may be considered a subset of models as they involve the comparison between two things that are similar in some respects. It 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. They are often used by scientists to explain abstract science concepts as well as when they are developing the complexity of their mental models. Coll, France and Taylor 2005 note that exemplary teachers share this strategy of using analogy with scientists when they are expressing complex abstract ideas.

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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 difficult and abstract science concepts. An analogy (or even metaphor) helps learners to understand and build knowledge of new concepts presented in class by calling up knowledge (memory) of concepts they have already mastered or become familiar with (Glynn & Takahashi, 1998; Allan & Treagust, 1993; Dunican, 2002; Ijioma & Onwukwe, 2011).

Several researchers have defined analogy differently. Glynn & Takahashi, (1998) defines an analogy as a mapping between similar features of concepts, principles, or formulas that are otherwise dissimilar. An analogy is a process of identifying similarities between two concepts. The familiar concept is called the base and the unfamiliar concept is called the target. By associating the features of the two concepts, students tend to acquire better understanding of the unfamiliar or target concept. Salih (2010) defined analogy as a concrete and visualisable representation of the matches and mismatches between the base and target concepts. Gentner (1983) cited in Brown and Salter (2010) defined analogy as a mapping of knowledge from the base to the target. Analogy is a mechanism which has been recognised by scientists, philosophers and psychologists alike as having the potential of bringing prior knowledge to bear on the acquisition of, sometimes, radically new information (Vosniadou, 1989). The term analogy refers to a cognitive process of transferring information or meaning from a particular object (the analogue or source) to another particular object (the target). Analogy is an inductive mechanism based on structured comparisons of mental representations (Holyoak, 2012). An analogy is a comparison through which an idea, a thing or a process is contrasted to another that is quite different from its counterpart. The aim is explaining that idea, thing or process by comparing it to something that is familiar.

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The use of analogy is often viewed as one of the primary means of drawing on students' prior knowledge. By activating relevant prior knowledge which is already understood by the learners, the analogy serves as a vehicle to bring meaning to incoming information (Brown & Clement, 1987). It can play a central role in the restructuring of students' conceptual frameworks (Duit, Roth, Komorek & Wilbers, 2001). Effective analogies motivate students, clarify students' thinking, help them overcome misconceptions and help them visualize abstract concepts (Orgil & Thomas, 2007). The discussions that occurs when using analogies help students construct their own knowledge and base the instruction on their prior knowledge and existing alternative conceptions. Knowledge is constructed in the mind of the learner and as they construct knowledge, they seek to give meaning to the information they are learning. Some of the abstract and challenging concepts in biology can be understood if analogy is used to illustrate the points (Gongden, 2016).

Analogies can be categorized based on relationship, presentation, content condition and level of enrichment (Harrison & De Jong, 2005; Spezzini, 2010). Table 1 summarizes the types of analogies.

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Table 1: Types of Analogies

Types of Analogies	Description
Based on Relationship	
➢ Structural	base and target share similar physical structures
➢ Function	base and target behave in similar ways
Based on Presentation Format	
➢ Visual/Pictorial	graphics (non-linguistic)
➢ Verbal	linguistic
➢ Pictorial-Verbal	both linguistic and graphics
Content Condition	
➢ Concrete to Concrete (C-C)	
➢ Abstract to Abstract (A-C)	
➢ Concrete to Abstract (C-A)	
Based on Level of Enrichment	
➢ Simple	grounds for comparison are not stated
➢ Enriched	grounds for comparison are stated
➢ Extended	comprises multiple enriched analogies that describe and explain the same target

Source: Harrison & De Jong (2005)

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In many analogies, the similarity of the objects is at a purely relational level. An example is the analogy that led to Kekuleís theory about the molecular structure of benzene (Holyoak & Thagard, 1995). In a dream, Kekule had a visual image of a snake biting its own tail which gave him the idea that the carbon atoms in benzene could be arranged in a ring. The similarity between the snake and the carbon atoms was at the purely relational level of a circular arrangement. The fact that the objects being compared in an analogy should be linked by the same relationships is widely accepted to be the hallmark of analogical reasoning. On the basis of certain similarities, a principle or characteristic of one term is applied to another term and asserted as true in that case as well.

Analogical reasoning is a key feature of the learning processes within a constructivist perspective; every learning process includes a search for similarities between what is already known and the new, as well as the familiar and the unfamiliar, to actively apply prior knowledge in a new situation (Wittrock & Alesandrini, 1990). Constructivist models of learning emphasize that connecting the new knowledge to be acquired with the existing knowledge is essential in order to promote meaningful learning (Limon, 2001). Meaningful learning occurs when students are not only able to remember knowledge, but also to transfer it to new situations. According to Duit *et al.* (2001), new conceptual frames are developed when transferring structures from familiar to new domains by establishing an analogy between the familiar and the unfamiliar.

Using analogies is not new in education; they have been used through the ages by researchers to help students understand theoretical concepts (Huddle, White & Rogers, 2000). Throughout the history of science, scientists and science educators and teachers have used analogies to explain fundamentally important discoveries and concepts (Brown, 1992; Clement, 1993; Lawson, 1993; Venville & Treagust, 1997). Analogies and analogical models

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have always been a key part of scientific reasoning from the eighteenth century onwards and have helped scientists understand, present and communicate about the phenomena and structure of the natural world (Glynn, 2007; Harrison & Treagust, 2006). They played a crucial role in the development of meaning in science and its progress and have been an essential element of scientific theories and explanations. The work of Boyle, Carnot, Darwin, Faraday, Kepler and Maxwell, for instance, reflects an extensive use of analogies in the construction of scientific models and theories (Guerra-Ramos, 2011; Marcelos & Nagem, 2010). Besides their role in the construction of knowledge, analogies facilitate the organisation, examination and communication of knowledge (Yilmaz & Eryilmaz, 2010). Commendable textbook authors such as Hewitt (2002), Campbell and Reece (2002), Echija, Bayquen, Alfonzo and De Vera (2003), as well as Palima and Ines (2004), also used analogies to explain science concepts. Yet, learning by analogies occurs not only in scientific contexts, politicians and other public figures often use analogies in their public performances and discussions. For instance, transformation of economic development towards sustainable development is accomplished through analogical reasoning from the source context of ecological systems to the target contexts of economic outcomes (Sriram, Ganesh & Mathumathi, 2013).

Science teachers, like scientists, frequently use analogies to explain concepts to students (James & Scharmann, 2007). The analogies serve as initial models, or simple representations of science concepts. The teachers frequently preface their explanations with expressions, such as, "It's just like," "Just as," "Similarly," and "Likewise." These expressions are all ways of saying to students, "Let me give you an analogy." Models and analogies are useful for transforming abstract, unfamiliar and seemingly incomprehensible ideas, concepts and theories into an intelligible realm of understanding for people in many contexts and circumstances. Science is a field replete with ideas that are difficult to visualize and often

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counter intuitive for pupils of all ages. It is not surprising, therefore, that models and analogies are important tools in the classroom repertoire of reputable science teachers (Harrison & Coll, 2008). Science teachers, science textbooks and lab manuals utilize models and analogies to captivate the conceptual attention of pupils (Aubusson, Harrison & Ritchie, 2006; Thiele, Venville & Treagust, 1995).

Studies have shown that analogy-based instruction has a positive impact on students' learning of science (Guerra-Ramos, 2011; Harrison & Treagust, 1993; Sarantopoulos & Tsaparlis, 2004). Analogies can boost student learning by providing visualization of abstract concepts, helping compare similarities of the students' real world with the new concepts, increasing students' motivation (Aubusson *et al.*, 2006; Harrison & Coll, 2008), enhancing students' conceptual change (Calik, & Kaya, 2012), improving academic performance and by acting as a memory aid which promotes retention ability (Al-Hinai & Al-Balushi, 2015).

Analogies can aid student learning by providing visualization of abstract concepts. Use of an analogy provides a bridge to access the abstract concept. 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 (background) of underlying concepts. 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 (Newby *et al.*, 1995). Science teachers frequently use analogies to explain concepts to students (James & Scharmann, 2007). These concepts often represent complex, hard-to-visualize systems with interacting parts: including genetics, evolution and ecology. Analogy draws a bridge from the concrete material world to the abstract domain (Dilber &

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Duzgun, 2008). Analogies allow new material, especially abstract concepts, to be more easily assimilated with students' prior knowledge, enabling them to develop a more scientific understanding of the concept. When students explore new concepts, meaningful learning proceeds when they find and visualize connections between a newly taught concept and what they already know (Dilber & Duzgun, 2008).

Using analogies during the instruction is another alternative strategy in promoting conceptual change. Analogies make new information intelligible to students by comparing it to the information that is already familiar to them. Students find topics more interesting when they have some relevance with their daily live and experiences. Many experimental studies have been carried out to probe the effect of analogies in learning complex scientific contents and promoting conceptual change (Calik & Kaya, 2012; Orgil & Bodner 2004; Savinainen, Scott & Viiri, 2005). Gentner, Brem, Ferguson, Markman, Levidow, Wolff and Forbus (1997) argue that using analogies is an everyday practice of science and in doing that, successful conceptual change takes place and creativity is fostered. Educational researchers argue that analogies can guide students towards conceptual change (Brown & Clement, 1987; Duit *et al.*, 2001). Podolefsky and Finkelstein (2007) conclude that analogies lead to conceptual change more readily than the abstraction and students may develop the skill of abstraction by building upon lower-level analogical thinking skills. As Duit *et al.* (2001) explain a growing body of research shows that analogies may be powerful tools for guiding students from their pre-instructional conceptions towards science concepts. Analogies enable students to reconstruct their understandings (Nashon, 2004). If introduced effectively, analogies present scientific knowledge as plausible and intelligible and make abstract concepts more comprehensible and visualisable (Dilber & Duzgun, 2008; Marcelos & Nagem, 2010; Paris & Glynn, 2004). These

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are some conditions for conceptual change to take place as proposed by Posner and colleagues as cited in Khourey-Bowers (2011).

Furthermore, analogies can increase students' motivation, interest and confidence in that, as the teacher uses ideas from the students' real world experiences, a sense of intrinsic interest can potentially be generated (Aubusson *et al.*; 2006; Venville & Treagust, 1997). They enhance students' intrinsic motivations by building up their confidence in their ability to tackle difficult concepts (Dilber & Duzgun, 2008; Guerra-Ramos, 2011).

The purposeful use of appropriate analogies can facilitate analogical thinking and transfer skills, as well as develop abilities which are required for life and lifelong learning, including successful integration into modern society and facility within our technology saturated world. Analogical thinking supports development of students' higher order thinking skills (Lolita, 2015).

There is a substantial body of literature which reports on the benefits of teaching with analogies, and their success in students' academic performance in science (Ayanda, Abimbola & Ahmed, 2012; Brown, 1992; Coll *et al.*, 2005; Dagher, 1994; Jaya, 2011). This is, in most part, due to the fact that everyday entities and situations are frequent sources for analogies (Sarantopoulos & Tsaparlis, 2004). Learners' familiarity with these everyday entities and situations makes analogies more effective in bridging the gap between a familiar and concrete domain (analogue) and an unfamiliar and abstract domain (target). The process of finding the correspondences between the two systems, which is called mapping or matching is what makes analogies an effective mental tool that loosens the abstractness of the newly introduced scientific entities and phenomena. They facilitate bridging between abstract and concrete learning experiences and provide students with an easy-to-imagine mental model. Thus, teachers use analogies to integrate previous knowledge into the new learning experience by

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activating related schemata and to help explain complex phenomena or processes (Clement, 2003). Their power lies in their ability to embrace a whole system of relations and features within the target phenomenon. In addition, the study of Gobert, O'Dwyer, Horwitz, Buckley, Levy and Willensky (2011), shows a positive relationship between the students' understanding of models and analogies and the depth of cognitive processing. Again, Chiu and Lin (2005) investigated how multiple analogies affect student learning of the concept electrical circuit. The results show that using analogies not only advanced the profound understanding of intricate science concepts but it also helped students correct their misconceptions of these concepts.

Analogies also act as a memory aid which promotes retention of new abstract target concepts (Glynn & Takahashi, 1998; Guerra-Ramos, 2011; Paris & Glynn, 2004). Akubuilo (2004) reported that any instructional model, which elicits adequate students' participation, has a profound effect on students' retention. Njoku (2004) opined that models and analogies concretize and elucidate difficult and abstract concepts thereby reduce students' problems of comprehension and application of concepts in problem solving. In this way models and analogies improve retention of knowledge and transfer of learning. Research findings have shown that analogy enhances performance and retention of concepts in science while researchers such as Owolabi (2007) have also shown that analogy improved student's performance and retention. Lagoke (2000) cited in Jiya (2011), reported that use of analogy arouse students' interest and imagination and therefore lead to understanding and retention of concepts. Glynn and Takahashi (1998) cited in Jiya (2011), opined that analogy enhanced learning of science by making it meaningful, that is making the target concept more understandable and memorable therefore improve students' retention. It may therefore be concluded that teaching science with analogy-based instructions may effectively help to

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improve students' conceptual understanding, academic performance and retention ability of biological molecular and abstract processes and concepts. In this study, analogy-based instruction was used to see whether the result is same or different in improving biology students' academic performance and retention in DNA structure and replication, transcription and translation.

Despite their advantages and usefulness, analogies can also cause incorrect or impaired learning depending on the analogue/target relationship. Some studies have shown that analogies do not necessarily enhance learner performance (Spezzini, 2010). Glynn (2007) warned that an analogy is a double-edged sword. It can cause misunderstanding among students. We need to admit that using analogies in teaching has not been always successful.

For instance proposed analogies are sometimes complex by themselves and require a high level of thinking to be comprehended. Thus, students are not able to conceptualise both the anchor analogue and the target concept (Guerra-Ramos, 2011; Podolefsky & Finkelstein, 2007). Also, sometimes when teachers use an anchor analogue to explain the relations within a target phenomenon, students focus on the comparisons between the anchor and the target in terms of physical attributes such as colour, size and rigidity instead (Podolefsky & Finkelstein, 2007). Students might judge some unrelated attributes as valid. As a result, they start to form alternative conceptions and thus, conceptualise the analogy differently from the manner the teacher intends (Harrison & Treagust, 1993). Also, science teachers themselves might not be familiar as to where a particular analogy breaks down (Guerra-Ramos, 2011). The process of misunderstanding starts when the comparison process considers detailed features in order to identify the similarities and dissimilarities between the analogue and the target (Guerra-Ramos, 2011). It also occurs when students are not warned of the limitations of the undertaken analogy and not given guidance on whether they should focus on the physical features or the

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functional attributes. There is sometimes a whole range of physical and functional attributes presented in one analogue-target comparison. Thus, classroom discussion of an analogy should lead students to explicitly identify the key related attribute(s) and the unshared ones within the given range of attributes (Guerra-Ramos, 2011; Harrison & Treagust, 1993; Marcelos & Nagem, 2010). For instance, the spiral staircase is used as an analogy to resemble the structure of DNA. Although this analogy focuses on a structural attribute, the shape of DNA, other physical attributes such as the rigidity of the staircase should be excluded. In addition, an important step in analogy-based instruction should be that once the analogy job to explain the target phenomenon is complete, the target should be separated from the analogy and extended by providing more examples and clarifications (Nashon, 2004).

By the same token, self-generated analogies might lead to personal explanations that are not in line with scientific consensus. Students assume ownership of their self-generated analogies and, consequently, they might over-generalise them to suit inapplicable contexts and omit the points of breakdown (Haglund & Jeppsson, 2012). Also, young students such as those in high school might not be capable of generating analogies that lead to successful conceptual change. They lack the ability to consistently maintain a well-developed analogy (Al-Hinai & Al-Balushi, 2015; Harrison & Treagust, 2006).

Also, superficial delivery and discussion of analogies without explicit elaboration and systematic mapping of target attributes verbally and visually lead to possible failure of analogy-based instruction (Paris & Glynn, 2004). In this respect, there is an underestimation of the role of visual imagery in learning science with analogies in both comprehension and retention of knowledge (Glynn & Takahashi, 1998). Unfortunately, literature shows that explicit elaboration of the similarities and dissimilarities between analogues and target

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concepts is not a frequent classroom practice and science teachers underestimate the difficulty that students might face when introduced to an analogy (Guerra-Ramos, 2011).

There is another failure of the analogy-based instruction. Given that analogues are easier to remember than the target concepts because of their familiarity to students, some students remember the concrete attributes of the analogy and not the abstract attributes of the target scientific concept. Therefore, students come up with alternative conceptions regarding the target phenomena based on their knowledge of their anchored analogue (Dilber & Duzgun, 2008).

It has also become apparent that analogies may deeply mislead students' learning processes. Conceptual change, to put it into other words, may be both supported and hampered by the same analogy (Duit *et al.*, 2001). If the teacher uses an analogy that is unfamiliar to the learner, development of understanding through use of that particular analogy is constrained. Some authors like Aubusson *et al.* (2006) and Dilber and Duzgun (2008) warn that the use of analogies in science, including biology teaching, does not always produce the intended effects; this is especially true when students take an analogy too far and are unable to distinguish it from the content being learned. Duit *et al.* (2001) stress that the analogical relations have a clear and fixed meaning from the perspective of the analogy provider. These meanings are often not shared with the students. Students are in a different position than teachers and textbook authors. The analogy may be viewed differently by learners and teachers, that is, brings about different observations. Students, therefore, may not see the analogy at all.

Hence when using analogies in the classroom, teachers should take time to consider particular strategies that will enhance both vocabulary and comprehension. Specific strategies such as Focus Action Reflection (FAR) guides by Harrison and Treagust (1993), Teaching-With-Analogies Model by Glynn (1991), Structure Mapping Theory (analogy maps) by Gentner

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(1983) and Multiple Analogies by Chiu and Lin (2005) suggest the usefulness of analogy as a tool for promoting meaningful learning and can be used within a variety of content subject areas in order to support student learning. These strategies were designed to help teachers maximized the benefits and minimized the constraints of analogies when they arise in classroom discourse or in textbooks.

Harrison and Treagust (1993) proposed the Focus Action Reflection (FAR) guide based on an extensive body of research with many schools, teachers and lessons,. The FAR guide has three stages for the systematic presentation of analogies and resembles the planning phases of expert teaching and the action research model.

- **Focus** refers to the decision about using the analogy when teachers initially consider the different aspects of the concept to be taught, whether or not the students already know something about the target concept: Is it difficult, unfamiliar or abstract? What ideas or prior knowledge do the students already have about the concept? Is it something analogue or familiar? In other words teachers recognize what difficult or abstract concept they want to teach and what analogy could be appropriate.
- **Action** refers to the class presentation when the teacher pays careful attention to the students' familiarity with the analogue and identifies the common and uncommon features of the analogue and target science concept or process. To achieve this, the features of the analogue and target are negotiated with students. Similarities and differences are drawn between them and ways that the analogue and the target are not alike are explicitly identified. Is the analogy clear and effective rather than confusing? The action phase usually involves at least three cognitive steps: familiarity with the analogue, mapping of the shared attributes and, then, negotiating with the students where the analogy breaks down.

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- **Reflection** takes place after the analogy has been used in class when the teacher discusses the clarity and usefulness of the analogy and draws conclusions. Reflection is characteristic of all good teaching and competent teachers implement this step in their pedagogical work. In summary, the FAR guide supports teachers to maximise the benefits and minimise the constraints of analogies when they arise in classroom discourse or in textbooks. Accordingly, it can be assumed that the teachers' ability to implement the FAR guide when teaching promotes deeper learning.

Teaching-With-Analogies Model which is developed by Glynn (1991) helps teachers use analogies systematically and effectively. Steps to using this model include the following:

- Introduce the target concept/word to students.
- Remind students of what they know of the analogue concept.
- Identify relevant features of the target concept and analogue concept.
- Connect (map) the similar features of the target concept and analogue concept.
- Indicate where the analogy between the target and analogue concept breaks down.
- Draw conclusions about the target concept.

According to Gentner's (1983) structure mapping theory, an analogy is a mapping of knowledge from one domain (the base/analogue) into another (the target) which conveys that a system of relations that holds among the base objects also holds among the target objects. A systematic comparison, verbally or visually, between the features of the analogue and target is called a mapping. Both the analogue and the target have features but the strength of an analogy lies less in the number of features of the analogue and target domains than in the system of connected information that it conveys (Gentner, 1983; Orgil & Thomas, 2007). To use the analogy is to complete a mapping from one structure to another. Gentner (1983) calls this theoretical framework structure mapping. For example, electric current is analogous to

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water flow. Aubusson *et al.* (2006) agree that the mapping of like and unlike attributes is essential to any effective pedagogy that uses analogy for science learning. According to Richland and Simms (2015), understanding the key steps of structure mapping is important in order to develop cognitively grounded insights for supporting higher order thinking: It is the process of representing information as systems of relationships, aligning and comparing/contrasting these systems to develop higher order relationships (such as same, different, or causal), and then drawing inferences, problem solving, and reasoning on the basis of those higher order relationships.

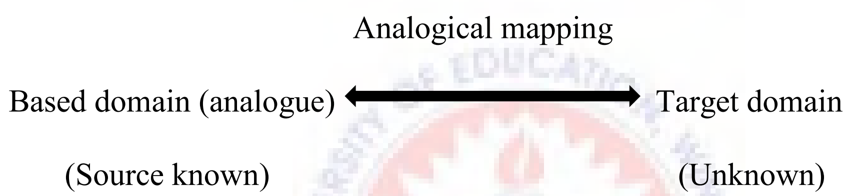

Figure 2: Analogical Mapping of Base and Target Domain (Adopted from Wilbers and Dult, 2006)

For complex and highly abstract concepts and processes, it might be useful to use multiple analogies to compensate for the deficiencies in single analogies. Previous works emphasise the role of multiple representations in fostering students' comprehension of complex scientific concepts (Nichols, Ranasinghe & Hanan, 2012). If a phenomenon is complicated, one analogy might work for one of its aspects and another analogy might be designed to explain another aspect of this phenomenon (Harrison & Treagust, 2006; Podolefsky & Finkelstein, 2007). For instance, while the water circuit analogy works well to explain the concept of batteries within the electric circuit, the moving-objects analogy works better to explain the concept of resistors (Podolefsky & Finkelstein, 2007). Also, multiple analogies allow students to select the most

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appropriate bridging method that links scientific concepts to everyday physical phenomena (Chiu & Lin, 2005). However, the analogies to be involved in the multiple-analogies approach should be carefully chosen as research indicates that multiple analogies might sometimes cause cognitive difficulties. It happens that the second analogy, when poorly chosen contradicts with the first one and consequently wipes out the positive accomplishment of the first analogy (Harrison & Treagust, 1993).

2.4.1 Examples of analogies use in the teaching and learning of biology

For example, biology abounds with anthropomorphic terms to describe everything from "messenger RNA" to "daughter cells" with associated visual imagery. The DNA code is in an alphabet spelled with four letters, the structure of DNA is described as a spiral staircase, and some genes are described as "selfish." The cell membrane is the gatekeeper, the Golgi apparatus the packaging department, the mitochondrion a power plant, and the lysosome is the suicide sac or stomach of the cell. The binding of an enzyme to its substrate is often compared to a lock and a key; and ATP is frequently referred to as a cellular energy currency in discussions of metabolism and reaction coupling. Neurobiologists compare the working of the brain to a computer and computer scientists are trying to design computers that work like the human brain - an interesting application of the dual nature and function of analogies! (Venville & Donovan, 2008). There are many analogies that teachers have developed to represent the process of protein synthesis.

According to Abimbola and Mustapha (2002), cited in Jiya (2011), the following are analogies that teachers have used in the teaching of biology concepts:

- The city analogy for a cell
- The (super) market analogy for a classification system

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- The rechargeable battery analogy for ATP
- The lock and key analogy for enzyme action
- The geography analogy for the human genome
- An Origami Paper Model for the Structure of DNA
- The spiral staircase analogy for the structure of DNA
- Lock and key model analogy for explaining DNA replication
- The Building a House Analogy for DNA transcription and Translation
- An Earth analogy for Cell Components
- The buckets and pumps analogy for the heart
- The brain is a computer, a metaphoric expression that gives insight into the structure and function of the brain from the perspective of the computer.
- Dice throwing as analogy to teach probability in genetics.
- The reference to oxygen as a lively gas.
- The reference to spinal cord as telephone cables.
- The description of the heart as a pump.
- The analogy of the embryo as a ball.
- The heating of a car analogy for the greenhouse effect

2.5 Concept of Animation-based Instruction in Science

Given the difficulties in teaching and learning of biological molecular concepts and processes, researchers who take a constructivist approach recommend enhancing the teaching of molecular concepts and genetics through educational methods that integrate modeling and visualization (Gilbert, 2003).

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One way to bring about a change of emphasis in teaching, from the teacher directed approach to a visualization and facilitated approach, is to change the medium of instruction (Kearsley, 2000; Kiili, 2005). One promising approach and alternative medium of instruction according to some authors, such as Chuang (1999), Kuti (2006), Mayer, Dow and Mayer (2003), Mayer and Moreno, (2002), Ozdemir (2009) and Taber, Martens and van Merriëboer (2004) is multimedia instruction. Multimedia instruction, according to Mayer and Moreno (2002), can be defined as presenting both *words* and *pictures* that are intended to foster learning. To Mayer and Moreno (2002), the word can be printed (e.g. on-screen text) or spoken (e.g., narration). The picture can be static (e.g., illustrations, graphs, charts, photos, or maps) or dynamic (e.g., animation, video, or interactive illustrations). According to Kommers, Grabinger and Dunlap (1996), multimedia refers to computer-based applications where users are provided with information through different types of media.

Worldwide, multimedia is now permeating the educational system as a tool for effective teaching and learning. It is increasingly providing richer environments for learning in a wide variety of formats. Multimedia is increasingly being used in many developed countries in computer-based narrated animation that explains how a causal system works and one rationale for this trend is the assumption that multimedia has properties that can aid learning, particularly the learning of abstract subject matter (Adegoke, 2010). In fact, in many developed countries, the use of computer-based instruction, and indeed information and communication technology in general (ICT), has been found, by many authors to be effective in enhancing students' learning outcomes (Coll, Rochera, Mayordomo & Naranjo, 2007; Garcia-López & Romero, 2009; Steinberg, 1991). This phenomenon according to Kuti (2006) is gradually being observed in developing countries too.

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An important example of multimedia instruction is a computer animation-based instruction or animation-based instructional approach (Chuang, 1999 in Adegoke, 2010). Animation as defined by Ukpebor and Ozobokeme (2007) is an art of making any objects into a motion with the aid of computer. Animation refers to a simulated motion picture depicting movement of drawn or simulated objects or moving something that cannot move by itself (Mayer & Moreno, 2002). The main features of this definition for animation are as follows:

- ✓ picture – an animation is a kind of pictorial representation
- ✓ motion – an animation depicts apparent movement and
- ✓ simulated – an animation consists of objects that are artificially created through drawing or some other simulation method.

According to Lowe (2003), animation is a dynamic/pictorial representation that can be used to make change and complex processes explicit to the learner. Animations are typically used by a teacher as a lecture supplement in the classroom or by students as individual learning tools.

In contrast, video refers to a motion picture depicting movement of real objects. Similarly, an illustration is a static picture of drawn (or simulated) objects whereas a photo is a static picture of real objects (Mayer & Moreno, 2002). Animations can be used to give an accurate and rich picture of the dynamic nature of molecules and molecular interactions, which are abstract in nature and often very hard to grasp from text-based presentations of information (Adegoke, 2010).

Animation-based instruction or Animation teaching on the other hands is defined as a multimedia-based instructional strategy which has the features of both verbal/narration and dynamic visual/pictorial presentations which are used in the teaching and learning process for effective dissemination of knowledge (Owolabi & Oginni, 2014; Thomas & Israel, 2014). It

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involves the program or instruction to be delivered which are recorded in a video tape or disc. This instructional approach applies to both the sight and hearing senses of the learner thereby fostering the retentive memory and recalling ability of the learners. The birth of pictorial (visual) forms of teaching has been observed to have developed as a counterpart to verbal forms of teaching (Lasseter, 2000; Lowe, 2004; Mosenthal & Pailliotet, 2000; Musa, Ziatdinox & Griffiths, 2013). Although verbal ways of presentation have long dominated education, the addition of visual forms of presentation has enhanced students' understanding (Sweller, 1999 cited in Musa *et al.*, 2013).

Recently, educational computer animation has turned out to be one of the most elegant multimedia tools for presenting abstract subject matter and materials to learners and its significance in helping to understand and remember information has greatly increased since the advent of powerful graphics-oriented computers (Adegoke, 2010). Animation has been used in various disciplines to deliver instructional material that is hard to present alone using static visuals or that contains content that is highly abstract or invisible to human eyes (Seel, 2012). Thus animations can have advantages over still picture representations, especially when dynamic or complex processes are to be depicted (Musa *et al.*, 2013). Animations can be utilized to show learners things not easily observed such as slow or fast processes or small structures invisible to the naked eye (Ainsworth, 2008).

Biology is an abstract and a formal subject and thus, it often results in learning difficulties of students (Fong, 2000). Computer animations are often used in biology courses to help students visualize complicated biological processes and concepts. Animations can facilitate understanding of complex spatial and temporal relationships that are difficult to depict in static images. Education research supports the claim that animations can lead to increased student learning and identifies features that make animations effective (Pruneski & Donovan, 2016).

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Because animations have the quality to portray abstract events and dynamic look, they have a positive effect on learning (Lewalter, 2003; Lowe, 2003). The abstract and dynamic nature of molecular biological processes and concepts such as DNA, RNA and protein synthesis has therefore made animation an important instructional media to help in teaching the concepts. Kylie (2012) noted that animations could be seen as a basic form of class entertainment which could pick the interest of all age groups, whether adult, teenager or a kid. The use of animation in the classroom is to engage the interest of the students, motivating them to learn and increasing independent and personal responsibility for education, higher thinking skills and creative in problem solving (Akor, 2011). Animations have been used in science teaching to enhance students' understanding of complicated science topics (Akpinar & Ergin, 2008; Ardac & Akaygün, 2004; Ebenezer, 2001; Weiss *et al.*, 2002). Furthermore Iravani and Delfechresh (2011), stressed that the flexibility of learning through animation allows a wider range of stimuli thus increases the students' engagement in learning which consequently translate into increase in level of students' academic performance and retention which is the priority of any educational system. Animations stimulate more than one sense at a time and therefore make them more attention-getting and attention-holding (Akpinar & Ergin, 2008). A number of studies were conducted on the impact of animation method in teaching and learning. Scholars like Barak, Ashkar and Dori (2010), Knowton and Morison (2002), Kim, Yoon, Whang, Tversky, and Morrison (2007) and Stith (2004) narrate that when a capable and enthusiastic teacher presents animation instruction systematically it provides a valuable way to communicate dynamic, complex sequences of events more effectively to students. Thus, the use of animation as a presentation strategy is particularly helpful when presenting highly abstract or dynamic process. Animation instructional strategy as an important tool for science education was further supported by studies. For example, Hoffler and Leutner (2007),

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Tayo (2012) and Thomas and Israel (2014) proved that animated images transform abstract idea into concrete images, thus improving the student's performance, understanding and attention. Both researchers and educational practitioners have believed that animation would facilitate learning because animations are more realistic for showing change. They can demonstrate in action the systems to be taught and animations can show change in time, they are thought to be natural and effective for conveying change in time (Nielsen, 1995; Kim *et al.*, 2007). In technology-aided education, visual materials such as animations, animated pictures and multimedia software have a great importance (Aldağ & Sezgin, 2002; Mayer & Moreno, 2002; Hall, 2012). Use of animations has a significant effect in teaching the abstract topics of science and technology courses.

Instruction with animations may increase conceptual understanding by prompting the formation of dynamic mental models of the particulate nature of matter. In this type of instruction, animations provided more scientifically correct visual models for submicroscopic processes. Animation facilitates descriptive and procedural learning and increases students' motivation (Lih-Juan, 2000; Mayer, 2001; Rieber, 1990). Animation is an important component in designing interactive multimedia which creates a visual interest and makes scientific learning more appealing and enjoyable for learners (Lih-Juan, 2000). Rotbain *et al.,* (2008) argued that students' misconceptions and difficulties in science can be overcome by using animations.

In fact, some concepts are taught in classrooms which deal with dynamic subject matter, and animation or graphic illustration is more favoured as a way of addressing the difficulties which arise when presenting such concepts verbally or numerically (Lowe, 2004). Instructional animations are valued for their ability to display temporal changes, as well as depiction of changes in position and form (Stith, 2004). The static cartoons of textbooks must contain

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symbols to depict change such as arrows that may appear cluttered and cause confusion. Also, there is less need for interpretation or inference with animations compared to a picture with arrows or other symbols (McClean *et al.*, 2005).

Animations are dynamic and engaging to the majority of learners as attention is better maintained by movement and colors, and animations are generally considered aesthetically pleasing. Learning styles are also served well through animations. Visual learners are exposed to transitional images, auditory learners may rely on the accompanying narrations, and even kinesthetic learners may benefit from a more complex, interactive animation that can be manipulated to explore the possible effects. The information is presented in a consistent manner, as all learners are presented with the same information in an identical format and reading comprehension is not an obstacle to learning (Polk, 2013).

Thus in order to have the students visualise the events happening in science and technology course, teaching with the support of concrete teaching aids can help the abstract knowledge to be shaped as concrete concepts (Atılboz, 2004). Animation is among the technologic options which can be used like that (Saka & Akdeniz, 2006). This technologic instrument has to be adapted to the knowledge of the student and the development of student's knowledge during the learning process (Schnotz, 2001).

Researches affirm that the use of animation in teaching has a significant increase for the students' attitude towards the course and academic achievement (Cepni, Tas & Kose, 2006; Katırcıoğlu & Kazancı, 2003; Powell *et al.*, 2003; Rowe & Gregor, 1999). Animations used in teaching not only had a significant increase in the students' attitude towards the course and academic achievements but also they had a lot of contributions such as safety, speeding up time, analysis of events rarely seen, simplifying complex systems, being practical and cheap, and enhance students' motivation (Güvercin, 2010; Tekdal, 2002).

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Knowton and Morison (2002) advocate that, when animation is used in teaching, it served five functions: connection; attention gaining; motivation; presentation and clarification functions. Animation, as a tool of education and training, has the advantages of: skill and ability improvement; interactivity; engagement; motivation; provision of immediate feedback; aid students through attracting and holding their attention (Ainsworth, 2008; Musa *et al.*, 2013; Russell, Kozma, Zohdy, Susskind, Becker & Russell, 2000; Sangin, Molinari, Dillenbourg, Rebetez, & Betrancourt, 2006; Scheiter, Gerjets, & Catrambone, 2006; Kehoe, Stasko, & Taylor, 2001; Weiss *et al.*, 2002).

Rotbain *et al.*, (2008) claimed that animation can illustrate and elucidate biological concepts more clearly and effectively than more traditional means – lecture, discussion or even conventional laboratory activities and such multimedia instructional environments hold potential for enhancing with the use of multimedia and audio-visual aids when teaching biology, physics, chemistry, basic sciences, technology and computer science.

There is still much debate surrounding this area; indeed animation presentations may be less useful for the purposes of education and training than was expected. Some teachers find it quite complex to use audio-visual aids (animations) to complement the traditional lecture method while others see the use of multimedia as waste of time (Owolabi & Oginni, 2014). In some cases, animation can even hold back rather than improve people's way of learning (Lasseter, 2000; Lowe, 2004; Mosenthal & Pailliotet, 2000; Musa *et al.*, 2013). Animation may possibly require greater cognitive processing demands than static visuals as the information changes frequently, especially critical objects, and thus cognitive connection can be lost during the animation (Hasler, 2007). Lowe (2004) indicated that the main problem that the multimedia (animation) developers, facilitators and instructors face is lack of principled guidance on how such instructional strategy should be designed and presented in order to

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facilitate comprehension. Mayer and colleagues have been examining the conditions under which animation promotes learner understanding and propounded seven research based principles for the design and use of multimedia presentations involving animation (for the use of animation in multimedia instruction). These principles are:

- **The multimedia principle:** The first principle is that students learn better/ more deeply from pictures (animation) and words than from words alone. The theoretical rationale for this principle is that students are better able to build mental connections between corresponding words and pictures when both are presented than when only one is presented and the learner must mentally create the other (Mayer, 2001).
- **The modality principle:** Students learn more deeply from animation and narration than from animation and on-screen text. The theoretical rationale is that the learner's visual channel might become overloaded when words and pictures are both presented visually, that is, learners must process the on-screen text and the animation through the eyes, at least initially. Thus, the learner might not have much cognitive capacity left over to build connections between words and pictures. In contrast, when words are presented through the auditory channel (as narration) then the visual channel is less likely to become overloaded, and learners are more likely to be able to build connections between corresponding words and pictures. (Mayer, 2001)
- **The temporal contiguity principle:** Students learn better or more deeply when corresponding portions of the narration and animations are presented at the same time than when they are separated in time. The theoretical rationale is that learners are better able to make mental connections when corresponding words and pictures are in working memory at the same time (Mayer, 2001).

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- **The coherence principle:** Students learn better or more deeply from animation and narration when extraneous words, sounds (including music), and video are excluded rather than included. The theoretical rationale is that the learner may attend to the irrelevant material and therefore have less cognitive resource available for building mental connections between relevant portions of the narration and animation (Mayer, 2001; Lowe, 2004).
- **The spatial contiguity principle:** Students learn better/more deeply when on-screen text is presented next to the portion of the animation that it describes than when on-screen text is presented far from the corresponding action in the animation. The theoretical rationale is that learners are better able to build mental connections between corresponding words and pictures when they are near each other on the screen; in contrast, when they are not near each other, learners must waste limited cognitive capacity in searching for the portion of the animation that corresponds to the presented text (Clark & Mayer, 2003).
- **The redundancy principle:** Students learn more deeply from animation and narration than from animation, narration, and on-screen text. It is based on the same theoretical rationale as the modality principle (Moreno & Mayer, 2000a; Taber, Martens & van Merriëboer, 2004).
- **The personalization principle:** The final principle is that students learn more deeply from animation and narration when the narration is in conversational rather than formal style. The theoretical rationale is that students work harder to understand an explanation when they are personally involved in a conversation (Mayer, 2001).

From the above principles, it means an effective use of animation with narration (animation-based instruction) is an approach to mediating cognitive load by leveraging the distinct

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processing mechanisms for visual and auditory information affirm by studies which have reported on how powerful and effective such combination (narrated animation) as an instructional strategy has been (Mayer, 2003; Paivio, 1986; Rieber, Tzeng & Tribble, 2004). Numerous studies have found that the use of narrated animations is an effective teaching strategy to increase conceptual understanding (Kim *et al.*, 2007; McClean *et al.*, 2005; McLaughlin, 2001; Rogers, 2007; Rotbain *et al.*, 2008; Stith, 2004)

The advantage of this combination is based, in part, on both cognitive load theory (Paas, Renkl & Sweller, 2003; Sweller, van Merrienboer & Paas, 1998) and dual coding theory (Paivio, 1986). This means that animation-based instruction or animation teaching can promote learner understanding when used in ways that are consistent with the cognitive theory of multimedia learning. According to the cognitive theory of multimedia learning, people have separate information processing channels for visual (pictorial) and for auditory (verbal) processing (Figure 3). When the learners face concurrent graphics on-screen text, both will be processed initially in the visual/pictorial channel. Since the capacity of the each channel is limited, both must compete for the same limited visual attention. In contrast, when the verbal explanation is in speech form, it enters the cognitive system through the ears and is processed via the auditory/verbal channel only. Simultaneously, the graphics enter the cognitive system through the eyes and are processed in the visual/pictorial channel. Thus, neither channel is overloaded. But both words and pictures are processed.

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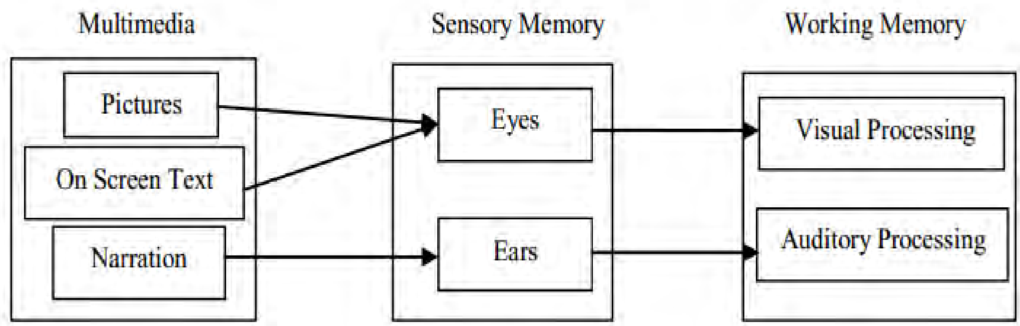

Figure 3: Access of Visual and Auditory Channels with Presentation of Narration and Graphics (Clark & Mayer, 2003).

These background studies prompted this study to use Animation-based instructional as a multimedia-based instructional approach which has the features of both verbal/narration and dynamic visual/pictorial presentations (Paivio, 1990 cited in Owolabi & Oginni, 2014). The researcher believed that animation-based instructional approach is the most effect multimedia-based instructional approach to improve students' academic performance and retention ability in science and biology in particular supported by previous studies which have revealed that animation had facilitated the learner achievement and retention than static visuals and other traditional instructional approaches (Ardac & Akaygün, 2004; Akpinar & Ergin, 2008).

2.6 Students' Academic Performance in Biology in Ghana

The study of biology is essential for the nation's scientific and technology development. Without sound knowledge and wholesome attitude towards biology, the much needed and vouched technological breakthrough may not be achieved. The knowledge of biology contributes to scientific literacy so that people can understand the world around them and enable them to make informal choices about their health care, their environment and the society in which they live (Karen, 2008). For instance the knowledge of biology is brought to

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play in the areas of manufacturing and processing industries, medicine, food production and pharmaceuticals among others.

Academic performance holds a prime importance in the field of education and is considered as the prerequisite for the progress of individuals (Rashmil & Bina, 2013). Academic performance as a variable in students' learning has been a matter of concerned in the present day research. Busari (2009) defines academic performance as the level of achievement in the subject as exhibited by an individual. According to Ogundukun and Adeyemo (2010), academic performance is the exhibition of knowledge attain or skills developed by students in the school subject usually designed by test scores or by marks assigned by teachers which can be low or high. Academic performance is one of the most intricate and controversial issues in education (Neghad & Shahraray, 2001). Academic performance of student is the chief indicators in evaluating the education (Gholami, Panahi, Neghad & Heidari, 2007; Paizi, Shahraray, Farzad, Ullah & Safai, 2007).

Unfortunately, research reports show that students' academic performance in biology is poor especially in Sub-Sahara Africa (Akubuilo, 2004). For example, Ghanaian students' performance in the subject has been reported to be consistently poor (Dzidzinyo, Bonney & Davis, 2014). According to Opara (2011), there is a high rate of failure in biology as revealed by the analysis of May/June SSCE result of 2006-2008. Statistics from the West African Examination Council (WAEC, 2016) revealed that performance in biology in the May/June examinations have been on the decline in Ghana. Of the total number of students who sat for the examination in the year 2016, the total percentage of candidates who attained credit level and above is 28% while 51.13% failed out rightly and areas students found it difficult to answer include cellular and molecular concepts and processes such as cell and cell division, genetics, evolution, and DNA, RNA and protein synthesis. Persistent poor performance in

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biology however has been attributed to a number of factors including teacher instructional approaches among others (Lawal, 2007; Usman, 2010; Atadoga, & Lakpini, 2013). Thus, instructional strategies used by teachers in teaching-learning process have significant influence on learners' academic performance.

In order to address this issue of low performance in biology, the WAEC chief examiner proffered remedies, one of which is adopting instructional delivery approaches and materials that make abstract concepts visible for the students in the teaching and learning process. This will promote imaginative, critical and creative skills in the learners resulting to better achievement of biological concepts (Federal Ministry of Education, Science and Technology, 2001; WAEC, 2016). Therefore, this study as part of its specifics objectives, sought to establish the effect of two instructional delivery approaches (analogy-based and animation-based instructional approaches) on biology students' performance in molecular biological processes and concepts particularly in areas such as DNA structure and replication, RNA transcription and translation (protein synthesis).

2.7 Concept of Student's Retention Ability

According to Hornby (2001), retention is the ability to remember a thing. Bichi (2002), sees retention as the ability to keep or retain and later recall information or knowledge gained after learning. Retention is defined by Kundu and Tutoo (2002), as a preservative factor of the mind. The mind acquires the materials of knowledge through sensation and perception. These acquired materials in the mind need to be preserved in the form of images for knowledge to develop. When a stimulating situation occurs, retained images are revived or reproduced to make memorization possible. Hence, biology concepts need to be presented to the learners in a way or method that touches their sub consciousness which can trigger quick recalling of the

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concept being taught or learnt. Okoye (2003) refers to retention as the process of maintaining the availability of new meanings or some part of them. It may be suggested that the amount of the original meaning that will be retained at any given point in time is a variable quantity. Therefore, forgetting represents a decrement in the availability of an acquired meaning. That is, it describes the loss in availability that occurs between the original establishment of the meaning and its later reproduction. Considering the two terms, retention is seen as referring to the positive aspects of memory while forgetting refers to the negative aspects.

Suleiman (2011) defines retention as the ability of one to remember what he has learned in the later time, it takes place when learning is coded in to memory. It is one of the four main elements of memory (others are learning, recall, and recognition). However, Mangal (2011) reports that these four elements have been replaced by three distinct stages (encoding, storage and retrieval). The storage stage is concerned with the power of retention of encoded information. According to Bichi (2002), permanent and meaningful learning is the target of our educational endeavor. Understanding and retention are the products of meaningful learning when teaching is effective and meaningful to the students.

Martin (1993) cited in Aninweze (2014) speculated that educators could improve retention of concepts and information by explicitly creating memorable events involving visual or auditory images through the use of animation, projects, plays, simulations, analogies and other forms of active learning. Frequent reviews and tests, elaborated feedback and active involvement of students in learning projects have all been associated with longer retention. Cope (2011) stated that active participation during instruction increases learning and retention. Lecturing is still a common way for instructors to communicate information. However, it does not allow for much interaction between learners and teacher and as a result, the instructor may falsely assume that the students fully understood the concepts that he presented. In order words,

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students learn more efficiently by participating in instruction. To further support this idea, Iji (2002) and Chianson (2008) stated that retention in biology is not acquired by mere rote learning but through appropriate instructional delivery strategy. Therefore, using instructional strategies that enhance visualization and active students' participation such as analogy, illustration, project work, concept mapping and animation-based instructional approaches can significantly improve learning and retention in students of all ages. This study as one of its specific objectives investigated the extent to which analogy-based and animation-based instructional approaches could improve students' retention in molecular biological processes and concepts particularly DNA structure and replication, transcription and translation concepts.

2.7.1 Measurement of retention ability

Okoye (2003) identified three methods of measuring retention which include; the recall method, the recognition method and the relearning or saving method.

- **The Recall Method:** this seems to be the method that is most familiar to every teacher. It requires the learner to recall as much as he can of the skills he has acquired. The measurement of vocabulary in a foreign language such as French may be measured by a recall test. In this test, the foreign (French) words may be presented and people are asked to give their English translation. Alternatively, the English words are given to be translated into French. Essay test typically calls for recall skills. Such a recall procedure is the least sensitive one available for measurement of retention.
- **The Recognition Method:** this method applies to the measurement of cognitive skills as are learnt in the academic classrooms. When this method is applied, the subjects demonstrate retention by recognizing a correct response. The objective type of

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examination is the most widely used example of this method of measuring retention. Every pupil and teacher knows that it is much easier to recognize the right answer than it is to produce an answer. In the recognition method of measuring retention, many cues are provided, but in the recall method, there are very few present to elicit the response. The difference in the number of cues present accounts for the difference in sensitivity of the recognition method in comparison with the recall method.

- **The Relearning or Saving Method:** some sensitive techniques have been developed that can demonstrate that there has been retention even though all the ordinary test of retention used in schools indicates that there has been one. A very sensitive technique widely used in laboratories is known as the saving method. In this method, the subject learns the material to a certain level of proficiency. If he is learning a list of words, then he may learn them to the point where he can repeat the list back perfectly on three successful occasions. If twenty-five repetitions might be required in the initial learning series to reach the point of perfect recall, only five repetitions might be required at later time to reach the same point of learning. Now, since on relearning, five instead of twenty-five repetitions were required, it might be said that on relearning, there was a "saving" of eighty percent. This is how the method got its name. In some studies, it has been the only method so far developed that is sensitive enough to provide evidence that there has been some retention of the original material learnt.

Having briefly examined the three major methods of measuring retention, it becomes necessary to relate these ideas to the present study. The recall method (fill in test type) and recognition method (objective test type) were used in this study to ascertain the subjects' retention abilities in the molecular concepts.

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2.8 Empirical Studies

2.8.1 Empirical Studies on Analogy-based and Animation-based Instructions

Uzma (2016) worked on "Effectiveness of Animation-based and Analogy-based instructions on Tenth-Grade Students' Achievement in Chemistry in Kishanganj, Bihar, India: A Comparative Study". This paper investigated the effects of teaching one of the most fundamental concepts of Chemistry 'Acids and Bases: Strong and Weak' using Traditional Teaching (TT), Traditional Teaching supplemented with Analogies (TTA) and Traditional Teaching supplemented with Computer Animations (TTCA) on students' achievement in Chemistry. A total of 90 tenth-grade students participated in this pretest-posttest control group quasi-experimental study. The Control Group (n = 30) was taught by TT, whereas the two Experimental Groups EG1 (n = 30) and EG2 (n = 30) were subjected to TTCA and TTA respectively. An analysis of covariance (ANCOVA) on Chemistry achievement post-test scores with students' pre-test scores as the covariate showed that Traditional Teaching supplemented with Computer Animations (TTCA) was more effective in enhancing the students' achievement acids and bases in Chemistry than both TTA and TT. It is, therefore, suggested computer animations are good tools for teaching acids and bases in Chemistry.

2.8.2 Empirical Studies on Analogy-based Instruction

Jiya (2011) investigated the effects of teaching-with-analogy on academic performance and retention of evolution concepts among NCE biology students in Nigeria. A total of 280 students consisting of 100 females and 180 males formed the sample for the study. Purposive sampling technique was used because the population was small. The subjects were divided into two groups; the experimental group N=135 and the control group N=145. The study adopted the pretest, posttest, post-posttest quasi experimental and control group design. A

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pretest was administered before the treatment to establish the equivalence of the experimental and control groups. The subjects in the experimental group were taught using Teaching-With-Analogy (TWA), while the control group subjects were exposed to the lecture method for a period of six weeks. The topics taught were evolution concepts. The researcher instrument designed Evolution Achievement Test (EAT) was adopted from biology textbook questions and past moderated NCE III examination questions. These were validated for data collection. Three null hypotheses were tested and t-test statistic was used to determine significant difference of the two groups at 0.05 level of significance. The major findings from the study include the following: there was significant difference in the mean academic performance scores of experimental and control groups in favour of experimental group. There is a significant difference in the retention ability of the students taught using analogy compared to those taught using lecture method of instruction in favour of experimental group. On the gender related issue Teaching-With-Analogy favoured male students over the female. Based on the findings it was concluded that NCE biology students learn evolution concepts better when taught using teaching-with-analogy. It was therefore recommended that Teaching-With-Analogy should be used by biology teachers to teach the concepts of evolution.

Ayanda, Abimbola and Ahmed (2012) examined the effects of teachers' use of analogies on the achievement of Senior School Biology Students at Oro in Kwara State of Nigeria. Differences in senior school students' achievement in biology, based on gender, when analogies are used was also investigated. A total of one hundred and ninety nine (199) students comprising 110 males and 89 females in senior secondary school two, were purposively sampled from four schools in Oro. The sampled students were assigned into two groups, experimental (97 students) and control (102 students). The reliability of the instrument was determined by administering the test to forty students of another school not participating in

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the study and the reliability coefficient of 0.73 was obtained using Pearson Product Moment Correlation Coefficient, at 0.05 alpha level of significance. The test scores were analysed using mean scores, *t*-test and analysis of covariance on the hypotheses formulated. Findings from the study showed that there is a significant difference in the achievement of the experimental group exposed to analogies and the control group exposed to the conventional method. The mean score of the experimental group was 18.73 compared to conventional group with the mean score of 15.32. The study also indicated that there is no significant difference in the achievement of male and female students in animal cell when they were taught using analogies. It was hereby recommended, among other things, that biology teachers should incorporate innovative instructional strategies, like analogies into their conventional teaching method for their teaching and their students' learning of biology

Sani (2006) made a study on effect of analogy on conceptual understanding of chemical equilibrium among form two senior secondary school students (S.S.S. 2). Eighty (80) S.S.S. 2 students in Minna of Niger State were used for both experimental and control group. The instruments used for posttest were two forms of multiple-choice chemistry tests which were used for data collection. The result obtained from the data analysis indicated that scores of the experimental and control groups before the treatment were 23.3 for experimental group and 24.9 for control group. This indicated that there was no statistically significant difference between the mean score of experimental group and the mean score of the control group at the 0.05 significant level (t =1.81, df =39, p<0.05) before the treatment. Thus the two groups were equivalent before the treatment. The result of the posttest mean scores of the experimental 56.7 and control groups 31.3 indicates that there is statistically significant difference between the mean scores of the experimental group and control group at the 0.05 level (t =1.52, df = 39, p<0.05). Thus, the null hypothesis was rejected. The experimental group taught with analogy performed significantly better than the control group taught with lecture method. The significant difference observed could be attributed to the effect of the experimental strategy which had increased conceptual understanding of the chemical equilibrium and consequently higher performance of the experimental group.

Nawaf (2016) also examined the effectiveness of analogy instructional strategy on undergraduate students' acquisition of organic chemistry concepts in Mutah University, Jordan. A quasi-experimental design was used in the study; Participants were 97 students who enrolled in organic chemistry course at the department of chemistry during the academic year (2015–2016) at Mutah University in Jordan. Two classes of the same teacher, one was randomly considered to be the experimental group (n=38) while the other was considered to be the control group (n=44). Ten analogies were used in the experimental group, the topics of alkanes, alkenes, alkynes, ethers, carbonyl compounds, aldehydes, ketones and carboxylic acids have been studied in chemistry course. All of the analogies were prepared by the researcher. During four-week period; each group received an equal amount of instruction. The chemical concepts achievement test consisted of 20 multiple-choice questions was administered as pre-test, post-test. After the treatment (post-test), experimental group had mean score of 15.05 while control group had 14.29. The results showed that there is significant difference in achievement between those students taught using analogy instructional strategy and those who were taught using traditional method ($t = 3.278$, $p = 0.002$).

Ugwumba and Bitrus (2014) investigated the effects of analogy instructional strategy, cognitive style and gender on senior secondary school students' achievement in some physics concepts in Mubi Metropolis, Nigeria. Instructional strategy at two levels was crossed with two levels of cognitive style and two levels of gender which served as moderator variables. A 2x2x2 matrix, pre-test, post-test, control group, quasi-experimental design was employed for matching the factors. Data were collected using two validated and reliable instruments namely: the Cognitive Style Test (CST) and Physics Achievement Test (PAT). A total of 82 senior secondary school two (S.S. 2) students from four schools took part in the study. Data were analysed using mean, t-test, factorial analysis of variance (ANOVA) and Least Significant Difference (LSD) Post Hoc Mean Comparison Test. The result revealed that there is significant difference in physics achievement between those students taught using analogy instructional strategy and those who were taught using lecture method (df =80, t = 0.02, F = 82.44, p = 0.000 < 0.05) in favour of analogy group. Thus the results showed significant main effect of treatment on achievement and significant interaction effect on achievement when cognitive style was crossed with gender. The more effective treatment was the analogy instructional strategy. Also, students' gender has no significant main effect on achievement in the post test PAT score (F= 0.59, p= 0.4449 > 0.05). Similarly, when students' gender was considered with treatment, there was no significant interaction on achievement (F = 0.04, p = 0.8362 > 0.05).

Lagoke (2000) investigated the retention ability of two groups of students. The experimental group was taught biological concepts using the analogical linkage strategy while the control group was taught same concepts using the lecture teaching method. The results showed that the experimental group performed significantly better and retained more of the biology concepts taught than their counterparts in the control group retain.

2.8.3 Empirical Studies on animation-based instruction

Rotbain, Marbach-Ad and Stavy (2008) studied on the use of a Computer Animation to teach High School Molecular Biology. The experimental group was taught using computer animation-based method while as control group was taught with tradition lecture-based

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method. Composite scores, calculated for the post-test were used to compare the groups using t- test on two groups. The data analysis showed that the mean score (73) of the experimental group was significantly higher ($p < .001$) than the mean score (61) of the control group. That is the students in the computer animation group significantly outperformed the control group on a content knowledge measure. The differences were highly significant across all the three subtopics examined: structure of DNA and RNA; the conceptual relations between genetic material and product; the molecular processes: replication, transcription and translation. The study only looked at the effect of animation-based instruction on student achievement in molecular concepts and processes in area like DNA and RNA.

Ayotola and Abiodun (2010) investigated on the effect of Computer Animation on the Academic Achievement of Nigerian Senior Secondary School Students in Biology. The moderating effects of mental ability and gender were also investigated. The pretest-posttest, control group, quasi-experimental design with a 2x2x2 factorial matrix was adopted for the study. A total of 189 Secondary School II biology students were involved in this study from Federal Government Colleges in South Western Nigeria using intact classes. Their age range was 14-16 years; 115 males and 74 females were involved in the study. The control Group (n = 80) was taught by conventional lecture method, whereas the two Experimental Groups EG (n=109) were subjected to computer animation respectively. Data collected from the BAT were analyzed using Analysis of Covariance (ANCOVA) to determine the impact of computer animation, gender, and mental ability, with pre-test scores as the covariate. The data analysis showed that there is a significant main effect of computer animation use on students' achievement in biology [F (1,176) = 21.33; $p < 0.05$]. The analysis also showed that there is no significant main effect of gender on student achievement in biology [F (1,176) = 0.036; p

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> 0.05] as whereas interaction effect of treatment and gender on students' achievement in biology [F (2,176) = .007; $p > 0.05$].

Thomas and Israel (2014), worked on effectives of animation and multimedia teaching on students' performance in science subjects. A sample of 100 students was randomly selected from four secondary schools in Ado Ekiti Local Government Area, Ekiti state. Quasi-experimental research design of two groups – pretest posttest control design. The result of three hypotheses distracted were analyzed using t-test. The result shows that there is significant difference in the academic achievement of students exposed to animated media teaching [t-calculated = 6.12 > table 1.98, w = 100, X = 23. 92, 90.66, SD (4.73, 6.43), df = 98] over the lecture method.

Yusuf and Afolabi (2010) investigated the effects of computer assisted instruction on secondary school students' performance in biology. Also the influence of gender on the performance of students exposed to computer assisted instruction in individualized or cooperative learning settings was examined. The research was a quasi-experimental involving a 3*2 factorial design. The sample of the study comprised 120 first year senior secondary school students (S.S.S. 1) sampled from three private secondary schools in Oyo state, Nigeria. The students pre-test and post test scores were subjected to Analysis of Covariance (ANCOVA). The findings of the study showed that the performance of students exposed to computer-assisted instruction (CAI) either individually or cooperatively were better than their counterparts exposed to conventional classroom instruction. However, no significant difference existed in the performance of male and female students exposed to computer assisted instruction in either individual or cooperative settings.

Polk (2013) studied the effect of teaching biology concepts with animations versus static cartoons via Power Point Presentation (PPP) on content retention. The research study adopted two activity groups: experimental and control groups. Students were pre-tested prior to the introduction of content in three units of study; cellular transport, protein synthesis and mitosis. A sample of eighteen students was randomly arranged to the experimental and control groups. The experimental group viewed an animation on the topic using PPP and accompanied by teacher narration while the control group viewed a series of static cartoons with captions through PPP. The two groups were post-tested together immediately following the treatment and again approximately 21 days later. The data collected was analysed using a Kruskal-Wallis (non-parametric ANOVA analog), along with a Dunn's Multiple Comparisons test to determine if any statistically significant differences existed between the means of control and experimental group. At 0.05 level of significance, the result showed that no statistically significant differences due to animations were found in these comparisons, though student engagement and class discussion were increased by the use of animations based on teacher observations. A class survey revealed an overwhelming interest in continued use of the animations as an instructional technique to increase students' retention of biology content.

Stith (2004) of the University of Colorado Denver, tested the effect of using animations in addition to lecture in his undergraduate Cell Biology class. In a class of 58 students he presented a lesson on apoptosis using Power Point slides, four of which explained the path to apoptosis involving the mitochondrion using both notes and static illustrations. At the end of the lesson, 27 randomly selected students were asked to wait in the hall as the remaining 31 students viewed a 65-second animation illustrating the same path to apoptosis. The animation was viewed four times. The other students were brought back in and all 58 students were given a quiz of 11 questions. Students who viewed the animations scored significantly higher on quizzes (14%) than those students who did not view animations.

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Adebayo and Oladele (2016) investigated the effects of Computer Simulation Instructional Strategy on Biology Students' Academic Achievement in DNA replication and transcription. The effects on retention ability and gender were also examined. The pretest-posttest, post posttest, quasi experimental control group design was used for the study. DNA Replication and Transcription Achievement Test (DRTAT) was developed and administered on fifty undergraduate 300 level Biology Education students from Ekiti State University (affiliated with Michael Otedola College of Primary Education, Epe) selected as the participants. The reliability coefficient of DRTAT was established at 0.70 using Kuder-Richardson 20 (KR 20). Experimental group was taught using computer simulation instructional strategy while the control group was taught using lecture method. Null hypotheses were verified at $p \leq 0.05$ levels using t-tests. Result showed that there is a significant main effect of computer simulation on students' mean achievement score in DNA replication and transcription. There was also a significant effect on the retention ability of students but no significant effect on gender was observed. The computer simulation was effective in enhancing students' achievement scores and retention ability therefore, computer simulation is recommended as a means of teaching DNA replication and transcription among Undergraduate Biology students in Nigerian university other tertiary institution.

Trevisan, Oki and Senger (2009) compared two groups of students who used a traditional lecture and animation as the learning material respectively. The learning topic was about follicular dynamics, a topic in physiology. The students invited for the study were from an undergraduate reproductive physiology course in six universities in USA. An immediate one-off test was used as the evaluation instrument. The results in general showed that those used animation as the learning material got significantly higher marks.

2.9 Summary of the Literature Reviewed and the Implication on the Present Study

Literature reviewed covered many previous works done in relation to the problems students have with the learning of biological concepts particularly, molecular concepts. Of particular interest is the failure of the traditional method of teaching to enhance students learning, achievement and retention. Many research works have been found that analogy-based instructional approach and animation-based instructional approach have significant impact on students' performance and retention in complex and abstract biological concepts. However, the difficulties students go through in learning abstract biological concepts such as DNA structure and replication, transcription and translation persists. From the literature reviewed, analogy-based and animation-based instructional approaches among others, facilitate students' achievement and retention regardless of grade level or subject matter.

However, it was observed from the review that most of the studies did not examine the comparative effects of these three instructional approaches: analogy-based instructional approach, animation-based instructional approach and convectional lecture-based approach rather they compared either analogy-based instructional approach or animation-based instructional approach with convectional lecture-based approach or with other conventional instructional approaches. There had been only one study in which the author compared the effectiveness of Animation-based and Analogy-based instructional approaches on Tenth-Grade Students' Achievement in Chemistry in Kishanganj, Bihar India (Uzma, 2016). All other literature did not directly compare the effect of the analogy-based and animation-based instructional strategies on students' performance together. This therefore means that more research on comparative study of analogy-based and animation-based instructional approaches needed to be done, a gap the present study sought to fill. Again from the literature, no work had been done on the present topic where both analogy-based and animation-based

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instructional approaches were used in the same study to determine their comparative effect on SHS biology students' academic performance on molecular biology concepts especially in areas like DNA structure and replication, transcription and translation; let alone their comparative retention effect, a gap the present study sought to fill. Furthermore, there are areas of difference between various literature reviewed and the present study. Such differences as geographical scope of the study, sample size, subject area, instructional strategies, and method of statistical analysis. Most of the research done on the use of analogy-based or animation-based instructional approach on students' learning in science especially biology, were at the international level. They were conducted in countries like China, USA, UK, Australia, Malaysia, India, Turkey, Germany and Nigeria, a gap to fill using Ghana and those few ones conducted in Ghana were carried out in areas different from where the present study was conducted. Hence, the purpose of this study was to compare the effectiveness of analogy-based and animation-based instructional approaches on students' academic performance and retention in DNA structure and replication, transcription and translation concepts in the Tano North Municipal of the Brong Ahafo Region, Ghana using second year general science students.

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CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter describes the method used in carrying out the study. The chapter includes the following sub-headings: Area of study, research design, population of the study, sample and sampling technique, data collection instrument, validity and reliability of instrument, data collection procedure, control of extraneous variables and data analysis.

3.1 Area of Study

The study was carried out in two selected Senior High Schools (Boakye-Tromo Senior High/Technical School and Yamfo Anglican Senior High School) in the Tano North Municipal with Duayaw Nkwanta as the Municipal capital in the Brong Ahafo Region of Ghana. This study area possesses all the necessary facilities like electricity, conducive classrooms and personnel needed for carrying out the research. Students' difficulties in senior high school biology and poor performance have also been identified in this area. The study area is also familiar to the researcher which made collection of data effective.

3.2 Research Design

This study adopted 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 study used two intact general science classes, one each from the two selected schools and randomly

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named them as experimental group 1 and 2. Boakye Tromo Senior High/Tecnical School was named as experimental group 1 and the Yamfo Anglican Senior High School as experimental group 2. This means there was no control group in this study because treatment was administered to all the two groups. The groups were randomly assigned to one of the two treatments. Thus experimental group 1 and experimental group 2 were randomly assigned to analogy-based (AGIA) and animation-based (AMIA) instructional approaches respectively. Both groups were taught the DNA concepts for a period of two weeks using conventional lecture-based approach and tested at the end of the second week which served as pre-treatment test scores. The groups were taught the topic again for another two weeks by the researcher using their respective assigned treatment. After treatment, DNACAT was administered to the subjects of the two groups as posttest to compare the effectiveness of analogy-based and animation-based instructional approaches as while as the conventional lecture-based approached employed in the teaching of the concepts. After three weeks of administration of the post-test, DNACAT was administered to the subjects in the two groups as delayed-posttest to determine the retention ability of the subjects in the concepts taught. The same test was administered as pretest, posttest and delayed-posttest. Symbolically, this design is represented in the Figure 4.

$$E_1 \longrightarrow X_0 \longrightarrow T_1 \longrightarrow X_1 \longrightarrow T_2 \longrightarrow T_3$$

$$E_2 \longrightarrow X_0 \longrightarrow T_1 \longrightarrow X_2 \longrightarrow T_2 \longrightarrow T_3$$

Figure 4: Design of the Study

Key:

E_1 = Experimental Group 1(Boakye Tromo Senior High/Tecnical School)

E_2 = Experimental Group 2

X_0 = No treatment (using conventional lecture-based instructional approach)

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X_1= Treatment for Experimental Group 1 (Analogy-based instructional approach)

X_2= Treatment for Experimental Group 2 (Animation-based instructional approach)

T_1 = Pre- treatment test

T_2 = Post- treatment test

T_3 = Delayed post- treatment test (Retention test)

3.3 Population of the Study

The target population for the study was all elective biology Senior High School students in the Tano North Municipal of the Brong Ahafo Region (N=1058), while the accessible population was all General Science biology students in Boakye Tromo Senior High/Technical School (N=118) and Yamfo Anglican Senior High School (N=123) totaling 241. The factors that were considered for the selection of the schools included: students' performance in biology at WASSCE (2013, 2014, 2015, 2016 and 2017) were not encouraging as while as students' difficulties in learning biology and poor performance in the internal examinations have been identified in this school. Each of the schools had seven elective biology classes with necessary facilities like science laboratory, electricity, conducive classroom, a library stocked with elective biology textbooks and personnel needed to carry out the research. Lastly, the school was attended by students from both rural and urban areas and the researcher is also familiar with the selected schools.

All the second year general science elective biology students' in the two schools totaling seventy nine (79) constituted the sample size, with an average age of 16 years plus. They were considered appropriate for the study because the topic (DNA structure and replication, transcription and translation) considered in the study is in the second year of the biology

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syllabus and also more stable compared to first years who had just arrived in the school some few months and the third years who were preparing for the WASSCE.

3.4 Sample and Sampling Technique

Boakye-Tromo Senior High/Technical School (n = 39) and Yamfo Anglican Senior High School (n =40) second year General Science intact classes totaled seventy nine (79) were purposively sampled for the study and they were the only second year General Science classes in the schools. These two intact classes, thus Boakye-Tromo Senior High/Technical School second year General Science class (n=39) and Yamfo Anglican Senior High School second year General Science class (n=40) were purposively renamed as experimental group 1 and 2 respectively. These two experimental groups were randomly assigned to one of the two interventional approaches (treatment). The experimental group 1 (n = 39) was assigned to the analogy-based instructional approach (AGIA) while the experimental group 2 (n = 40) was assigned to the animation-based instructional approach (AMIA). The sample is viable in accordance with Central Limit Theorem that recommends 30 participants as minimum sample size for experimental study (Tuckman, 1975; Usman, 2000; Jiya, 2011). There was no control group for this study, however each intact class was taught the topic (DNA structure and replication, transcription and translation) with conventional lecture method for two weeks, pretested, before they were regrouped into the two experimental groups for the various treatments for a period of another three weeks. The pre-test helped the researcher to determine the striking difference in the performance of the two groups in terms of distance they travelled after the execution of the treatment. The detail of the sample is presented in the Table 2.

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Table 2: Distribution of students in the Two Instructional Approach Groups

Group	Male	Female	Total
Analogy-based Group (Experimental Group 1)	30	09	39
Animation-based Group (Experimental Group 2)	29	11	40
Total	**59**	**20**	**79**

3.5 Data Collection Instrument

Generally one instruments was used for data collection in this study. It was DNA Concept Achievement Test (DNACAT).

The DNA Concept Achievement Test (DNACAT) was made up of twenty (20) multiple choice test items, five (5) true or false items and five (5) fill-in the blanks. The researcher, 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 researcher. Each multiple choice test item has 4 options A, B, C, D, of one key and three distracters and each correct answer attracts one mark totaling twenty (20) marks for the objective questions. The other ten (10) questions (true or false and fill-in the blanks test items) also sum up to 10 marks making over all marks for DNA Concept Achievement Test (DNACAT) totaling thirty (30) marks. This test was designed to measure students' cognitive performance and retention

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ability in the DNA structure and replication, RNA transcription and translation (protein synthesis) concepts. The test was intended to determine the knowledge, comprehension and application levels of students related to the concepts. Detailed of the DNA Concept Achievement Test (DNACAT) and its making scheme can be are shown in Appendices B and C respectively.

3.5.1 Validity of Instrument

Validity can be defined as the degree to which an instrument measures what it is supposed to measure (Christine, 2013). The DNACAT was subjected to both face and content validity scrutiny by experts in the subject area. Face validity is the evaluation of an instrument's appearance by a group of experts and/or potential participant. The face validity point out that the instrument is pleasing to the eye and applicable for intended purpose (Burton & Mazerolle, 2011). On the other hand, content validity refers to the appropriateness of the content of an instrument. That is, content validity determines whether the questions accurately assess what one want to know (Biddix, 2009). The DNACAT was validated by two Senior Lecturers in Science Education of University of Education, Winneba including my supervisor, two biology teachers who have been teaching biology for over ten years and an English Language Specialist who validated the items of DNACAT with respect to language clarity. These experts gave both face and content validity of the instrument such as:

- Clarity of instructions
- Correct wording of test items to avoid ambiguity
- Appropriateness and adequacy of the test items in addressing the purpose and problem of the study
- Checking for possible errors in the instruments and suggest corrections

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- Considering the percentage allocation of the various levels of the content units that were covered according to Blooms taxonomy
- Ensuring equal number of items for each topic or unit been reflected according to the curriculum content of the units

After validation exercise, most of the items in the instruments were found to be satisfactory and met the requirement of content validity, as per the agreement of all the experts. Based on the critique and suggestions from the experts, the researcher made amendments such as reframing some of the test items before the final items were used for pilot testing.

3.5.2 Pilot Test

Third year General Science biology students at Bechem Presbyterian Senior High School was purposively and conveniently selected for the pilot testing of the instrument (DNACAT). This school had similar characteristics as one used for this study. The reason for pilot testing of DNACAT was to establish the validity and reliability of the test items. It was also used to ascertain the discrimination and difficulty indices of the test items. Administering instrument to pilot subjects in exactly the same way as it will be administered in the main study helps to ask the subjects for feedback (Teijlingen & Hundley, 2011). The pilot test helped to identify and discard all unnecessary, difficult or ambiguous questions, and provided the opportunity to re-word or re-scale any question that was not answered as expected. It helped to record the time taken to complete the DNACAT and decided whether it was reasonable.

3.5.3 Discrimination Index

Discrimination index (DI) refers to power or ability of a test item or instrument to distinguish between good student and a weak student (high and low scorers). Thus, the difference between

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the percentage of students in upper and lower groups who got the items correct. A good test item or test instrument should be able to clearly discriminate or differentiate between good and weak students (Hotiu, 2006). The discrimination index was calculated for each test item of the DNACAT. To calculate the discrimination index, the marked papers were arranged from highest score to the lowest score. The papers (N=40) were grouped into three: upper, middle and lower groups using top 27% (11 students), bottom 27% (11 students) and the middle group consisting of the remaining 46% (18 students). The discrimination index was then estimated using the following formula:

$$\text{DI} = \frac{RU - RL}{\frac{1}{2}N}$$

Where:

DI = discrimination index

RU = number among the upper 27% of respondents who scored the item correct

RL = number among the lower 27% of respondents who scored the item correct

N= total number of the upper and lower respondents.

The range of values for the item discrimination index is -1.00 to 1.00.The higher the value of discrimination index, the more effective the item is. When discrimination index is 1.00, it means that all the participants or test takers in the upper group and no participant or test taker in the lower group answered the test item correctly. Conversely, if none of the upper group but all of the lower group answered an item correctly, the discrimination index value would be negative one (-1.00). Index close to zero (0) means that participants in both groups (upper and lower groups) performed almost the same in the item. For examination with a normal distribution, discrimination index of 0.3 and above is good; 0.6 and above is very good. The index should never be negative (Oosterhof, 1990). From the calculation of the pilot test, the discrimination indices for all the items in the DNACAT in the pilot test were found to be within the acceptable range (see Appendix D).

3.5.4 Difficulty Index (Facility Index)

The difficulty index which is also known as facility index for each item (question) of the DNACAT was calculated. The difficult index is the proportion or percentage of the entire students who answered or got the item correctly (Bhoopatiraj & Chellamani, 2013). It can also be interpreted as how easy or how difficult an item is. The formula for the item difficulty index is given as:

$$D_f = \frac{R}{T}$$

Where:

D_f = Difficulty index

R = the number of students who selected the correct answer

T = the total number of students who attempted the test item (question).

The difficult index ranges from 0 to 1. It can be converted to a percentage by multiplying by 100. The higher the difficult index, the easier the question. Santos (2009) recommended a benchmark for interpreting the difficulty index. Santos suggested that items with difficulty index of 0.00 to 0.25 means the item is difficult and needs to be revised or discarded, 0.26 to 0.75 means the item is appropriate and needs to be retained and 0.76 to 1.0 means the item is too easy and needs to be revised or discarded. After the calculation, items 7 and 19 were found to be too difficult and were modified and maintained (see Appendix D).

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3.5.5 Reliability of Instrument

Reliability is the consistency of measurement over time, whether it provides the same results on repeated trials (Christine, 2013). The DNACAT was pilot-tested by administering the tests to a sample of 40 students in one intact biology class of SHS 3 science students at Bechem Presbyterian Senior High School in order to obtain the reliability of the test items. These students were not involved in the main study but were equivalent samples of the group for which the instrument was developed.

Kudder-Richardson formula 20 (KR-20) was used to calculate the reliability and internal consistency of the DNACAT and it is given as:

$$\text{KR-20} = \frac{k}{k-1}\left(1 - \frac{\sum pq}{s^2}\right)$$

Where:

KR-20 = Kudder-Richardson formula 20

k = the total number of test items

Σ = indicates to sum

p = the proportion of the test takers who pass the test item

q = the proportion of test takers who fail the test item

s^2 = the variance of the total test scores (The variation of the total exam scores)

This method of estimating the reliability and internal consistency of an instrument is appropriate for dichotomously scored items (items with correct and wrong answers) such as the DNACAT which consists of multiple choice test items, true or false and fill-in the blanks with correct and wrong answers, and it is easier to use. The reliability coefficient of DNACAT

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was calculated to be 0.87. The reliability coefficient of 0.88 means that 87% of variability in scores is due to true score differences among the examinees, while the remaining 13% is due to measurement error. Thus, DNACAT was considered to be reliable enough for data collection in this study because it was within the acceptable benchmark of reliable instruments (Leedy & Ormrod, 2005) (See Appendix E).

3.6 Ethical Issues

Introductory letter was collected from the department of science Education to the authorities of the selected schools. The researcher also spoke to some of the teachers whose classes would be used and the students involved of the aims and purpose of the study and the need for the participants to give their consents and cooperation. Regarding the site where the research takes place and gaining permission before entering the site is very paramount in research (Creswell, 2002). The researcher assured them of confidentiality and their informed consent. According to Kelley, Clark, Brown and Sitzia, (2003), these are the most important ethical issues to adhere to when conducting a research.

3.7 Data Collection Procedure

The researcher sought an approval from the schools authorities to carry out the study in their schools. The two experimental groups were first exposed to the DNA structure and replication, transcription and translation concepts by their biology teacher using the convectional lecture-based instructional approach for the period of two weeks. This instructional approach emphasized direct lectures given by teacher, interactive discussions between the teacher and students, use of textbook materials, still pictures and charts, and clear explanation of important concepts to students, but no use of animations and analogies was done. The teacher did not incorporate the use of any animations and analogies in his lesson plans. That is, the biology

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teachers who taught the subjects (students) the DNA concepts using convectional lecture-based instructional approach strictly followed the detailed lesson note prepared by the researcher and vetted by the subject experts and they were also monitored during the instructional periods by the researcher. The subjects (students) were then tested at the end of the second week convectional lecture-based instructional period using pre-DNACAT which was printed in light green coloured papers. Pre-DNACAT scores served as data to measure students' performance before the introduction of the treatment and also whether the two groups are within the same entry point in terms of performance the introduction of the treatments

Each of the two experimental groups was randomly assigned to one of the two treatments using balloting method. The experimental group 1 was subjected to the analogy-based instructional approach (AGIA) while the experimental group 2 was subjected to the animation-based instructional approach (AMIA). The groups were exposed to their respective treatment (instructional approach) for another two weeks by the researcher. That is, the teaching of the two experimental groups was done by the researcher. This was to ensure that the teaching procedures are followed accordingly as required by the various interventional instructional strategies (treatments). It also removes teacher bias that might arise when using research assistants. Each group attended four periods per week with each period having forty (40) minutes duration and each lesson was a double period which lasted for eighty (80) minutes. The post-DNACAT was administered right after the second week treatment period. Post-DNACAT scores served as data to measure students' performance. The delayed/post post-DNACAT was administered three weeks after the posttest and it was to measure the extent to which each of the treatments (analogy-based and animation-based instructional approaches) has improved the students retention. Thus the post/delayed post-DNACAT

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(retention test) is necessary to determine how the two groups differ in remembering the content learnt. The test items in pre-DNACAT were reshuffled and printed in white coloured papers to make them appear different at a glance and avoid the students cramming the questions and administered as post-DNACAT to determine their performance after the treatment. Again the items in the post-DNACAT were reshuffled and printed in light yellow coloured papers and administered as delayed post-DNACAT three weeks after the post-test. Students' submitted both their answer booklet sheet and question papers in all the three tests and at the end of each test the researcher marked and recorded the scores. The data collected from the tests scores were analysed to answer research questions and test the research hypotheses.

3.8 Treatment Design

The two treatments used in this study were designed in the form of lessons and delivered using their respective approaches, that is, analogy-based and animation-based instructional approaches.

3.8.1 Analogy-based instructional approach

Experimental group 1 in this study was subjects (students) exposed to analogy-based instructional approach which involved the use of lecture method supplemented with appropriate analogies. The teacher incorporated analogies such as *"Building a House Analogy and Bread Baking Analogy" for DNA Transcription and Translation"* in his lesson plan. When using analogies in the classroom, teachers should take time to consider particular strategies that will enhance both vocabulary and comprehension. Hence strategies such as Focus Action Reflection, (FAR) guides by Harrison and Treagust (1993), Teaching-With-Analogies Model by Glynn (1991), Structure Mapping Theory (analogy maps) by Gentner

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(1983) and Multiple Analogies by Chiu and Lin (2005) were used to teach each topic. These strategies were designed to help teachers maximized the benefits and minimized the constraints of analogies when they arise in classroom discourse or in textbooks. During the instruction, some analogies were showed directly to students in the classroom by using the required materials. However, the pictures of other analogies were drawn on the blackboard and presented to the students. During the presentation of the analogies in the classroom, students were assisted to both join the lesson and make a connection between the concepts and analogies with the help of a few questions. They were asked as part of their homework, to think of an analogy to the concepts taught in the lesson. In this way, the teacher contributed to the maximum participation of students in the lessons. At the end of the presented analogies (after the discussion between the students) the teacher explained the similarities and differences between the analog and target concepts again. Therefore, the students who made an incorrect connection between the analog and target concepts were able to re-organise their opinions. The content was delivered to the group for a period of two weeks with two lessons per week (80 minutes per lesson). Some of the analogies used to teach DNA structure and replication, transcription and translation concepts: *Building a House Analogy and Bread Baking Analogy* (multiple analogies) are shown in Appendix F.

3.8.2 Animation-based instructional approach

Experimental group 2 in this study was subjects (students) exposed to animation-based instructional strategy which involved the use of lecture method supplemented with appropriate animation. The teacher therefore incorporated animations software downloaded from www.wapwon.com/video/category/dna_replication,wapspot.mobi/tube/ download/dnar/FBO_mXxlwandcontent.dnalc.org/c15/15510/transcription_basic.mp4 and

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other website in the lesson plans. Enabling environment for the conduct of animation teaching at the pre-animation stage was provided. That is providing the computer, projector, animated software on the concepts and supply of standby power source to avoid interruption throughout the lesson. The computer and projector were connected to the power source and the software was installed in the computer for the lesson. In addition, objectives of the lesson were clearly stated and explained to the students. The next stage is content delivery or animation stage, where the teacher begins with brief introduction of the lesson to the students. This is then followed by power point projection of the developed animated package/ animation software in the class based on topic of discussion. Each episode is projected on the screen and students were actively participating in observing, recording, and discussing of the presentation and jotting down of core points. The role of teacher is facilitating and clarification of points unclear to students. It should be noted that after each episode teacher interacted with students in answering questions with a view to remedy some areas of difficulties observed during lesson. This treatment also lasted for two weeks with two lessons per week (80 minutes per lesson i.e. double period per lesson). Some snapshots in the animations used to teach students in the animation-based Instructional Group in DNA structure and replication, transcription and translation concepts is shown in the Appendix G.

3.9 Control of Extraneous Variables

Extraneous Variables are undesirable variables that influence the relationship between the variables that an experimenter is examining. Another way to think of this, is that these are variables the influence the outcome of an experiment, though they are not the variables that are actually of interest. These variables are undesirable because they add error to an experiment. A major goal in research design is to decrease or control the influence of

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extraneous variables as much as possible. The following measures were adopted to control some of the extraneous variables in this study:

- **Initial group differences:** Randomization is one of the procedures of controlling initial group differences in an experimental study, however, this was not done in the present study. Instead, two intact classes were sampled. Thus, to control initial differences of subjects and reduce error variance in the two sampled classes, both groups were taught the topic by their biology teacher with conventional lecture-based instructional strategy, tested to ensure that there were no statistically significance difference between the two groups in terms of academic performance before the introduction of the various interventions
- **Variability of instructional situation:** Homogeneity of instruction across groups was ensured as their biology teachers conducted the conventional lecture based teaching while the researcher also conducted the treatments and they strictly followed the detailed lesson note prepared by the researcher and vetted by the subject experts and they were also monitored during the instructional periods by the researcher. Also all the two groups were taught the same topics within the regular periods allocated to biology in their schools time table to ensure that the difference is due to the instructional strategy applied.
- **Testing effect:** To control testing effect, the pre-DNACAT items were reshuffled and printed in different coloured question papers before it was used as post-DNACAT and delayed post-DNACAT (retention test). The pre-test items which were printed in light green question papers were rearranged and printed in white question papers before used as post-test application (post-DNACAT). The post-test further rearranged, produced in a yellow question papers and used as the retention test application

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(delayed post-DNACAT). The reshuffling and different colour question papers ensured that research subjects (students) would not recognized the pre-test questions or post-test questions based on their serial numbers and colour of the question papers. The students did not also know that they would be given retention test (delayed post-DNACAT) after three weeks of administering post-DNACAT to avoid any attempt from them to remember the test items from the first or second application.

3.10 Data Analysis

Scores from the students in the pre-DNACAT, post-DNACAT and delayed post-DNACAT form the data for the study. Data were analyzed using various statistics including mean, standard deviation, Wilcoxon signed rank test, Mann-Whitney test, paired sampled *t*-test, independent sample *t*-test, Cohen *d* effect size and one way analysis of covariance (ANCOVA) at 0.05 level of significance. Computation for the above-mentioned methods of data analyses were done using statistical package for social sciences (SPSS) version 20 which was employed for both descriptive and analytical techniques.

The research questions one (1) and two (2) were meant to determine the effect of analogy-based and animation-based instructional strategies respectively on biology students' performance in DNA structure and replication, transcription and translation concepts within each group. Mean, standard deviation, Cohen *d* effect size, box plot and Wilcoxon Signed Rank Test together with paired samples *t*-test were used to answer research questions 1 and 2. Wilcoxon signed rank test together with paired samples *t*-test was used to answer the research questions 1 and 2 because the sample was purposively selected before randomly assigned to the two instructional approaches. Wilcoxon Signed Rank Test is the non-parametric alternative to the paired sample *t*-test (repeated measures *t*-test), but instead of comparing

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means as in the case of paired sample *t*-test, the Wilcoxon signed rank test compares median, that is, it converts scores to ranks and compares them at Time 1(or condition 1) and at Time 2 (or condition 2). It is therefore essential and appropriate to use these analysis tools together to answer research questions 1 and 2 because two observations (pre-treatment test and post-treatment test) were made on each student in the analogy-based and animation-based instructional groups in order to determine whether the performance of the students within each group improved or not after the treatments were executed. Effect size was also estimated to determine the magnitude of improvement in each group. Again, boxplot was also used to give pictorial representation of the performance of the students in the pre-DNACAT scores and post-MCPT scores. The dependent variable for research questions 1 and 2 was the achievement scores (DNACAT scores) the students obtained in both pre and post-tests while the independent variable was the instructional approach (analogy-based instructional approach and animation-based instructional approach)

To answer research question 3 and its corresponding hypothesis 1 which was to examine the comparative effect of analogy-based and animation-based instructional approaches on biology students' performance in DNA structure and replication, transcription and translation concepts, mean, standard deviation, independent samples t-test together with Mann-Whitney test, Cohen *d* effect size and box plot statistics were used. Mann-Whitney test also known as Wilcoxon rank sum test is the non-parametric alternative to the independent sample t-test, which is used for independent samples, Instead of comparing means of the two groups, as in the case of the independent sample t-test, Mann-Whitney test converts the scores to ranks, across the two groups and evaluates whether the ranks for the two groups differ significantly. Effect size was also used to determine the extent of improvement in performance between the groups while the boxplot was also used to give pictorial illustration of the performance of the

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students between the groups. The dependent variable for research questions 3 was the achievement scores (DNACAT scores) the students obtained in post-test whereas the independent variable was the instructional approach (analogy-based instructional approach and animation-based instructional approach)

To answer research question 4 and its corresponding hypothesis 2, thus to analyse the comparative effect of analogy-based and animation-based instructional strategies on biology students' retention ability in DNA structure and replication, transcription and translation concepts, mean, standard deviation and one-way analysis of covariance (ANCOVA), effect size and box plot were used. The ANCOVA was used to test the hypothesis 2. Pre-DNACAT served as covariate in the ANCOVA analysis to control for any pre-existing differences between the groups. Delayed post-test scores (retention scores) was the dependent variable while the independent variable was the instructional approach (analogy-based instructional approach and animation-based instructional approach). ANCOVA statistic is very useful in situation where the difference existing between the groups has small or medium effect size. Effect size was also calculated to determine the magnitude of the retention ability between the groups. Again, boxplot was also used to give pictorial representation of their retention ability performance.

3.10.1 Calculating effect size

The term 'Effect Size' describes indices that measure the magnitude of the treatment effects. Statistical significance is the least interesting thing about the results. You should describe the results in terms of measures of magnitude – not just, how does a treatment or treatment affect people, but how much does it affect them (*Kline, 2004).* The effect size is the main finding of a quantitative study. While a *p*-value can inform the reader whether an effect exists, the *p*-

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value will not reveal the size of the effect. In reporting and interpreting studies, both the substantive significance (effect size) and statistical significance (*p*-value) are essential results to be reported (Sullivan & Feinn, 2012). Effect size analysis enables the researcher and reader to judge the practical significance of a research results.

The effect size for each of the research question and hypothesis in this study was calculated using **Cohen's *d* effect size**. Cohen's *d* is known as the difference of two population or sample means and it is divided by their pooled (average) standard deviation from the data. Mathematically Cohen's *d* effect size is denoted by the formula:

$$d = \frac{\bar{x}_2 - \bar{x}_1}{S_p}$$

WhereS_p is the pooled (average) standard deviation of the two groups. For the independent groups (independent samples *t*-test), pooled standard deviation (S_p) can be calculated using this formula:

$$S_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

Where

$\bar{x}_1$and $\bar{x}_2$= sample means of group 1 scores and group 2 scores, respectively

s_1 and s_2= sample standard deviation for each group (or s_1^2 and s_2^2 = sample variances for each group)

n_1 and n_2 = sample sizes for each group.

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For the dependent group (paired samples *t*-test), pooled standard deviation (s) can be calculated using the formula:

$$S_p = \sqrt{\frac{s_1^2 + s_2^2}{2}}$$

Cohen (1988) provided rules of thumb for interpreting these effect sizes, suggesting that *d*=0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size. This means that if two groups' means do not differ by 0.2 effect size or more, the difference is trivial (practically unimportant), even if it is statistically significant. Note that the effect size is not measured on a linear scale so an effect with *d*=0.4 is not twice as big as one with *d*=0.2.

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CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

The purpose of this study was to investigate the effects of analogy-based and animation-based instructional approaches on second year biology students' academic performance and retention in biological molecular concepts, especially DNA concepts, at the Senior High Schools in the Tano North Municipal of the Brong Ahafo Region. This chapter presents and discusses the main results of the study where both descriptive and inferential statistics were used for the analysis in response to the research questions and hypotheses with the support of statistical package for social sciences (SPSS) computer software version 20. Here, the core concern of the entire work was presented with the purpose of providing basis for conclusion and highlighting the study's contribution to knowledge.

4.1 Results of the Study

This section presents the main findings (results) of the study which is done in line with the research questions posed for the study. Both descriptive and inferential statistics were used for the analysis in response to the research questions and hypotheses with the support of statistical package for social sciences (SPSS) computer software.

In order to determine whether the two experimental groups selected from the two schools are equivalent in terms of knowledge in the concept, their pre-test scores obtained after they were taught with the same approach (conventional lecture-based approach) were analysed using independent sampled t-test. The result is shown in Table 3.

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Table 3: Testing the Homogeneity of the Two Experimental Groups before Treatment using Their Pre-test Scores

Instructional Group	N	Mean	SD	*df*	*t*-cal	*p*-value	ES (Cohen *d*)
Experimental Group 1 (Boakye-Troms SHTS)	39	16.62	4.37				
				77	1.14	0 .282	0.29
Experimental Group 2 (Yamfo Anglican SHS)	40	16.83	4.51				

Significance level, α = 0.05, SD = Standard Deviation, ES = Effect Size

Table 3 revealed that before treatment, experimental group 1 (second year general science students at Boakye-Tromo Senior High/Technical School) was at the same entry point with the experimental group 2 (second year general science students at Yamfo Anglican Senior High School) with both having a pre-test mean scores of 16.62 and 16.83 respectively. That is, there was no statistically significant difference between the two experimental groups prior to treatment (t (77) = 1.14, p=0.282 > 0.05).

4.1.1 Research Question 1: To what extent does the use of analogy-based instructional approach improve students' performance in DNA concepts?

To attest the effect of analogy-based instructional approach on students' performance in DNA structure and replication, transcription and translation 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-test (pre-DNACAT) and post-test (post-

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DNACAT) scores (Table 4). Also, box plot (Figure 5) was used to give pictorial illustration of the performance of the students in both pre-DNACAT and post-DNACAT scores which helped to judge the practical significance of the test scores.

Table 4: 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	0.000	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	0.000	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 4, the students' mean scores of the achievement test before and after the use of the analogy-based instructional approach are 16.62 (SD = 4.37) and 27.13 (SD = 2.39) respectively. There has been a mean gain (an increase) in the achievement test score from pre-test (prior to the treatment) to post-test (after the treatment). From the Table 4, it can be observed that the mean difference (mean gain score) between the pre-test and the

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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 concept of DNA structure and replication, transcription and translation (t (38) = 18.29, $p < 0.001$; $Z = 5.53$). 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 concept of DNA structure and replication, transcription and translation after been taught with the analogy-based instructional approach than when taught with conventional lecture-based instructional approach (prior to treatment).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 which implied that analogy-based instructional approach had positive and substantial effect on the students' performance after its treatment. Furthermore, the illustrations in the box plot (Figure 5) confirm the extent to which the students had improved in terms of performance in DNA structure and replication, transcription and translation concepts because of the use of analogy-based instructional approach.

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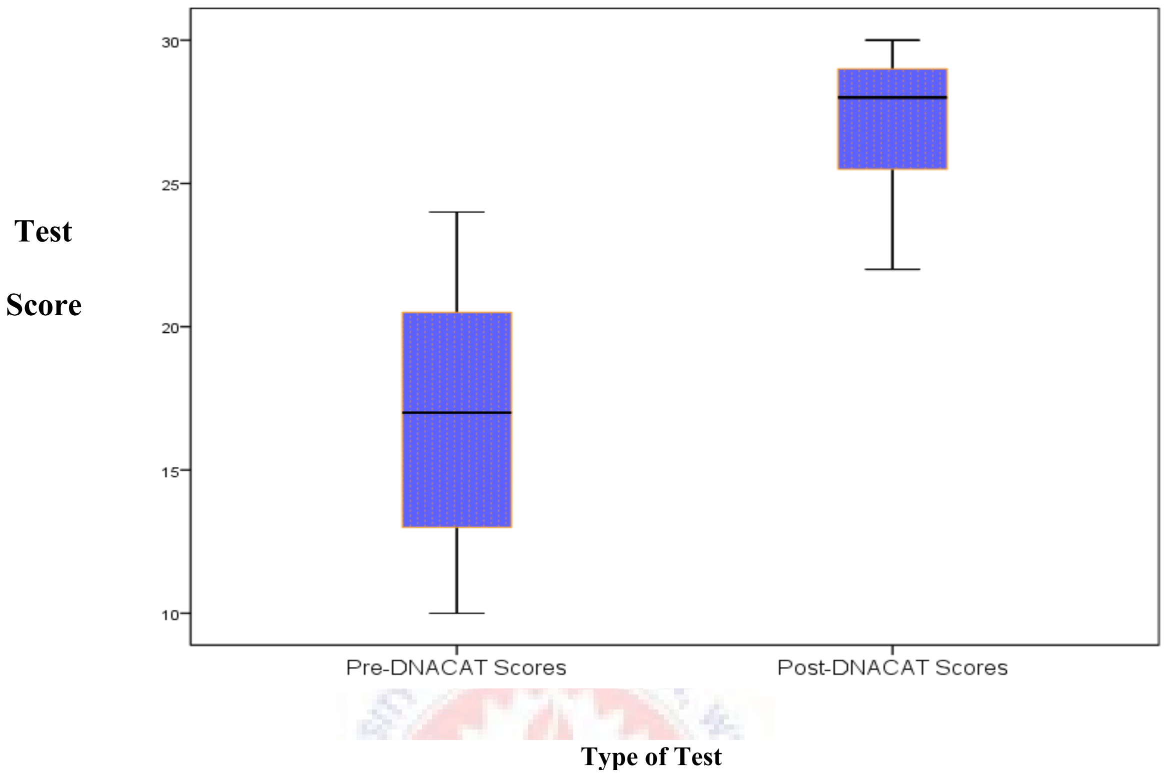

Figure 5: Performance of Analogy-based Instructional Group in the Pre-test (Pre -DNACAT) and Post-test (Post-DNACAT) Scores

It can be seen from the illustration of the box plot (Figure 5) that the students improved massively in their performance and understanding of the DNA structure and replication, transcription and translation concepts through the use of analogy-based instructional approach. From Figure 5, the minimum score recorded in the pre-test (prior to treatment) was 10 while the maximum score was 24. As a result of the treatment, the minimum score the students obtained from the post-test (after the treatment) which is 22, is more than twice the one obtained in the pre-test and almost equal to the maximum score they had in the pre-test. This implies that when analogy-based instructional approach is effectively employed, it could greatly enhance students' academic performance in the DNA structure and replication, transcription and translation concepts as while as other biological molecular concepts in general.

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4.1.2 Research Question 2: To what extent does the use of animation-based instructional approach improve students' performance in DNA concepts?

To determine the extent to which the use of animation-based instructional approach improves students' academic performance in DNA structure and replication, transcription and translation 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-test (pre-DNACAT) and post-test (post-DNACAT) scores (Table 5). Furthermore, box plot (Figure 6) was used to give pictorial illustration of the extent to which the students' academic performance had improved in the concepts of DNA structure and replication, transcription and translation, because of the use of animation-based instructional approach.

Table 5: Comparison of Pre-test and Post-test Scores of Students Taught with Animation-Based Instructional Approach (N=40)

Paired Samples t-Test

Test	Mean	SD	*df*	*t*-cal	*p*-value	ES (Cohen *d*)
Pre-test	16.83	4.51				
			39	16.98	0.000	2.53
Post-test	26.15	2.59				

Wilcoxon Signed Ranked Test

Test	Median	SD	*df*	*Z*-statistic	*p*-value	ES (Cohen *d*)
Pre-test	16.50	4.51				
			39	5.62	0.000	2.53
Post-test	26.00	2.59				

Significance level, α = 0.05, SD = Standard Deviation, ES = Effect Size

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From the results in Table 5, the students' mean scores of the achievement test before and after the use of the animation-based instructional approach are 16.83 (SD = 4.51) and 26.15 (SD = 2.59) respectively. There has been a mean gain (an increase) in the achievement test score from pre-test (prior to the treatment) to post-test (after the treatment). From the Table 5, it can be observed that the mean difference (mean gain score) between the pre-test and the post-test is 9.32. Data from the pre-test and the post-test achievement scores were subjected to paired samples t-test together with Wilcoxon Signed Ranked Test statistics at 5% significant level to determine if there is any significant difference between the mean difference. The result indicated that there is a statistically significant difference between the pre-test and the post-test achievement scores of the students in the DNA structure and replication, transcription and translation concepts ($t = 16.98$, $p < .001$; $Z = 5.62$). To know the extent of the effect of the animation-based instructional approach on the students' performance, effect size was calculated using Cohen *d* effect size statistic ($d = 2.53$). This shown that there was a large effect size which implied that animation-based instructional approach had positive and substantial effect on the students' performance. Pictorially, the difference between the students' pre-test and post-test scores in terms of distance travelled is shown in Figure 6.

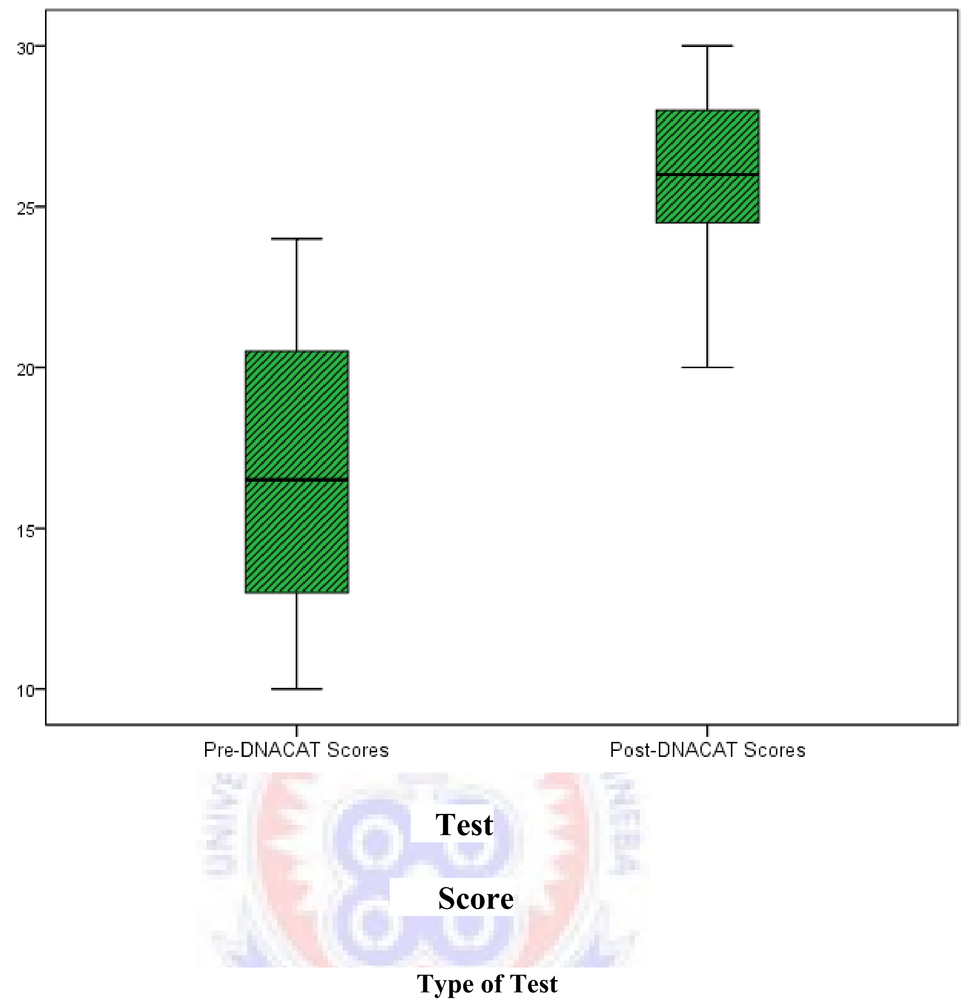

Figure 6: Performance of Animation-based Instructional Group in the Pre-test (Pre -DNACAT) and Post-test (Post-DNACAT) Scores

From Figure 6, it can be seen that the students improved tremendously in their performance and understanding of the DNA structure and replication, transcription and translation concepts through the use of animation-based instructional approach. For instance, it can be observed from the box plot that the minimum score the students obtained in the post-test (after the treatment) which is 20, is twice the one obtained in the pre-test (prior to treatment), which is 10. This means that when animation-based instructional approach is effectively used, it could improve students' academic performance in the DNA structure and replication, transcription and translation concepts and other biological molecular concepts in general.

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4.2.3 Research Question 3: What difference exist in performance between the students in analogy-based and animation-based instructional groups in DNA concepts?

To answer research question three (3) and its corresponding hypothesis one (1), that is, to examine the difference in performance between the students in analogy-based and animation-based instructional groups in DNA structure and replication, transcription and translation concepts, the mean, standard deviation, Cohen *d* effect size and independent samples *t*-test together with Mann-Whitney Test statistics were used to analyse the post-test scores (post-DNACAT scores) of the two treatment groups (analogy-based and animation-based instructional groups). The comparative performance of the two instructional groups (treatment groups) in the three cognitive levels: knowledge, comprehension and application level questions were examined before the analysis of the overall performance using independent samples *t*-test together with Mann-Whitney (see Table 6).

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Table 6: Comparing the Post-test Mean Scores (Performance Scores) of Analogy-based and Animation-based Instructional Groups

Independent samples *t*-test

Cognitive Level	Max. Mark	Instructional Groups	No.	Mean	SD	*df*	*t*	*p*	Effect Size (Cohen *d*)
Knowledge	10	Analogy-based	39	8.95	0.99	77	1.044	0.300	0.23
		Animation-based	40	8.73	0.91				
Comprehension	12	Analogy-based	39	10.62	0.94	77	1.234	0.221	0.28
		Animation-based	40	10.35	0.98				
Application	8	Analogy-based	39	7.56	0.68	77	2.863	0.005	0.63
		Animation-based	40	7.08	0.83				
Overall Test	30	Analogy-based	39	27.13	2.39	77	1.746	0.085	0.39
		Animation-based	40	26.15	2.59				

Mann-Whitney Test

Instructional Group	N	Mean Rank	SD	*df*	*Z*-statistic	*p*-value	ES (Cohen *d*)
Analogy-based	39	44.51	2.39	77	1.74	0 .082	0.39
Animation-based	40	35.60	2.59				

Significance level, α = 0.05, SD = Standard Deviation, ES = Effect Size
*Analogy-based instructional group = Boakye Tromo Senior High/Technical School Second Year General Science Students
*Animation-based instructional group = Yamfo Anglican Senior High School Students Second Year General Science Students

The results in Table 6 revealed that there was no significant difference in the mean performance score (post-DNACAT scores) between the two instructional (experimental) groups in terms of two cognitive levels: knowledge (t = 1.044, p = 0.300 > .05) and comprehension (t = 1.234, p = 0.221 > .05), although the analogy-based instructional group had the higher mean score in all the two cognitive levels (knowledge: $\bar{x}$ = 8.95, SD = 0.99 and comprehension: $\bar{x}$ = 10.62, SD = 0.94) compared to the animation-based instructional group (knowledge: $\bar{x}$ = 8.73, SD = 0.91 and comprehension: $\bar{x}$ = 10.35, SD = 0.98). However, there was a significant difference in the mean performance scores (post-DNACAT scores) between

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the two instructional groups in terms of the application cognitive level (application questions). The difference is in favour of the analogy-based instructional group (t = 2.863, p = 0.005 < 0.05). That is, students in the analogy-based instructional group ($\bar{x}$ = 7.56, SD = 0.68) outperformed the animation-based instructional group ($\bar{x}$ = 7.08, SD = 0.83) in the application questions of the post-DNACAT (post-test). To know the magnitude and the practical effect of the mean difference between the two groups in the application cognitive level questions, Cohen *d* effect size statistic was calculated (d= 0.63). This indicated that there was a medium effect size which implied that analogy-based instructional approach had positive but moderate effect on the students' performance in the application cognitive level questions of the concepts compared to animation-based instructional approach.

Again, there was no significant difference between the two instructional groups in the overall total score of the post-DNACAT (t = 1.746, p = 0.085 > .05; Z = 1.74, p = 0.082), however, the analogy-based instructional group ($\bar{x}$ = 27.13, SD = 2.39) had the higher mean achievement score with lower standard deviation compared to the animation-based instructional group ($\bar{x}$ = 26.15, SD = 2.59) in the overall total score of the post-test (post-DNACAT). The higher mean achievement score and low standard deviation by the analogy-based instructional group showed that most students in that instructional group gained mastery of the concept of DNA structure and replication, transcription and translation more than the group taught with animation-based instructional approach. Pictorially, the difference between the two instructional groups in terms of performance (post-test scores) is shown in Figure 7.

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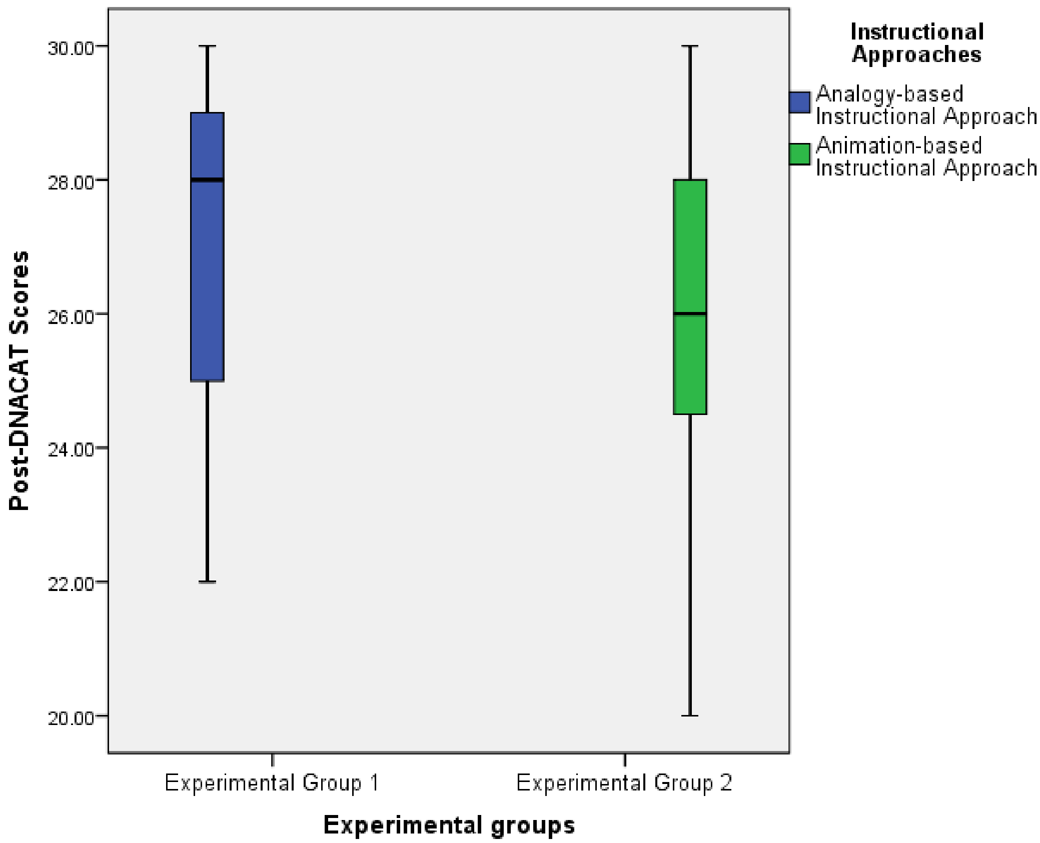

Figure 7: Comparing the Performance of Analogy-based and Animation-based Instructional Groups in the Post-DNACAT Scores (Post-test Scores)

From Figure 7, it can be seen that the analogy-based instructional group outperformed the animation-based instructional group in their performance and understanding of the DNA structure and replication, transcription and translation concepts. For instance, it can be observed from the box plot that the minimum score the students in the analogy-based instructional group obtained in the post-test was 22 which is higher than the minimum score in the animation-based instructional group, which was 20. It can also be seen from the box plot that the median score obtained from the analogy-based instructional group in the post-test was 28 which is higher than the median score obtained from the animation-based instructional group, which was 26. This means that when analogy-based instructional approach is effectively used, it could improve students' academic performance more than the

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animation-based instructional approach in the DNA structure and replication, transcription and translation concepts especially in the application questions (application cognitive level).

4.1.4 Research Question 4: What difference exist in retention between the students in analogy-based and animation-based instructional groups in DNA concepts?

To answer research question four (4) and its corresponding hypothesis two (2), that is, to evaluate the difference in retention between the students in analogy-based and animation-based instructional groups in DNA structure and replication, transcription and translation concepts, the mean, standard deviation, Cohen *d* effect size paired samples t-test and analysis of covariance (ANCOVA) were used to analyse the delayed post-DNACAT scores (retention test scores) of the two treatment groups (analogy-based and animation-based instructional groups). Paired samples t-test was used to examine the extent of decline in mean scores in each of the two instructional groups from post-DNACAT to delayed post-DNACAT (Table 7). Analysis of Covariance (ANCOVA) was then used to test the significance of the mean difference in the retention test scores (delayed post-DNACAT scores) between the two instructional groups, where the pretest scores were the covariates; delayed post-DNACAT scores were the dependent variable and the treatments at two levels (analogy-based instructional approach and animation-based instructional approach) were the independent variables. The result is presented in Table 8.

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Table 7: Mean Decline and Paired Samples *t*-test Results for Post-DNACAT and Delayed post-DNACAT Scores in the Two Instructional Groups

Instructional Group	$\bar{x}_P$	$\bar{x}_D$	Mean Decline. ($\bar{x}_p$ -$\bar{x}_D$)	SD	*df*	*t*	*p*-value	Effect Size (Cohen *d*)
Analogy-based (Boakye Tromo SHS)	27.13	23.44	3.69	2.85	38	8.068	.000	1.57
Animation-based (Yamfo Anglican SHS)	26.15	20.95	5.20	3.45	39	9.531	.000	1.96

$\bar{x}_P$ = Mean score of the post-DNACAT, $\bar{x}_D$= Mean score of the delayed post-DNACAT

Table 7 helps to examine the extent of decline in students' mean score from the post-test to delayed post-test in each of the instructional groups. It can be seen from Table 7 that analogy-based instructional group students had a statistically significant mean decline of 3.69 with large effect size ($t = 8.068$, $p < .001$, Cohen $d = 1.57$) between the post-DNACAT scores ($\bar{x}_P$= 27.13) and delayed post-DNACAT scores ($\bar{x}_D$= 23.44). Again, It can be observed from Table 7 that animation-based instructional group students had a statistically significant mean decline of 5.20 with large effect size ($t = 9.531$, $p < .001$, Cohen $d = 1.96$) between the post-DNACAT scores ($\bar{x}_P$= 26.15) and delayed post-DNACAT scores ($\bar{x}_D$= 20.95). It implied that students' in both analogy-based and animation-based instructional groups decline significantly in their respectively mean scores between the post-test and delayed post-test. However, students' in the analogy-based instructional group had a lower mean score decline of 3.69 compared to that of animation-based instructional group with mean score decline of 5.20, which implied that students in analogy-based instructional group did well in the retention of the DNA structure and replication, transcription and translation concepts. The difference in the mean

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score decline between the two groups is 1.51, however, to examine whether this difference is statistically significant, their retention test scores (delayed post-DNACAT scores) were subjected to one way ANCOVA, presented in Table 8 and 9. In other words, to statistically examine the comparative effectiveness of the two instructional approaches on the students' retention, their retention test scores (delayed post-DNACAT scores) were subjected to one way ANCOVA, presented in Table 8 and 9.

Table 8: Descriptive Statistics of the Two Instructional Groups on Delayed Post-DNACAT Scores

Instructional Groups	N	Mean	Std. Deviation
Analogy-based Instructional Groups (Boakye Tromo SHS)	39	23.44	2.30
Animation-based Instructional Groups (Yamfo Anglican SHS)	40	20.95	2.71

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Table 9: Summary of Analysis of Covariance (ANCOVA) of Retention Test Scores (Delayed Post-DNACAT Scores) of Students Taught with Analogy-based and Animation-based Instructional Approaches

Dependent Variable: Delayed post-DNACAT scores

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared (η_p^2)
Pre-DNACAT Scores (Covariate)	12.57	1	12.57	2.01	.160	.03
Instructional Approach (Treatment)	123.84	1	123.84	19.82	.000	.21
Error	474.92	76	6.25			
Total	39464.00	79				

From Table 8, it can be seen that analogy-based instructional group had a mean retention score (mean delayed post-DNACAT scores) of 23.44 (SD = 2.30) and that of animation-based instructional group was 20.95 (SD = 2.71). This means that there is a mean difference of 2.49 in favour of analogy-based instructional group. However, to test the significance of this retention mean difference of 2.49 and for that matter the research hypothesis two (2) which stated that: there is no significant difference in the mean retention scores of students taught DNA structure and replication, transcription and translation concepts using analogy-based and animation-based instructional approaches, one way ANCOVA was used to analyse the instructional groups' delayed post-DNACAT scores (retention scores) (see Table 9). It could be deduced from the Table 9 that there is a statistically significant difference in the mean

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retention scores of students taught DNA structure and replication, transcription and translation concepts using analogy-based instructional approach and animation-based instructional approach (F [2, 76] =19.82, $p < 0.001$, $\boldsymbol{\eta_p^2} = 0.21$). This implies that students taught with the analogy-based instructional approach significantly outperformed the students taught with the animation-based instructional approach in the retention test administration (delayed post-DNACAT scores). Again, partial eta square ($\eta_p^2 = 0.21$) which is the effect size indicating the magnitude of the mean difference between the two instructional groups in terms of the retention scores is large according to the benchmark provided by Cohen (1988) to define partial *eta* square(η_p^2). Moreover, the illustrations in the box plot (Figure 8) confirm the extent to which the students taught with analogy-based instructional approach outperformed the students taught with the animation-based instructional approach in terms of retention of the DNA structure and replication, transcription and translation concepts.

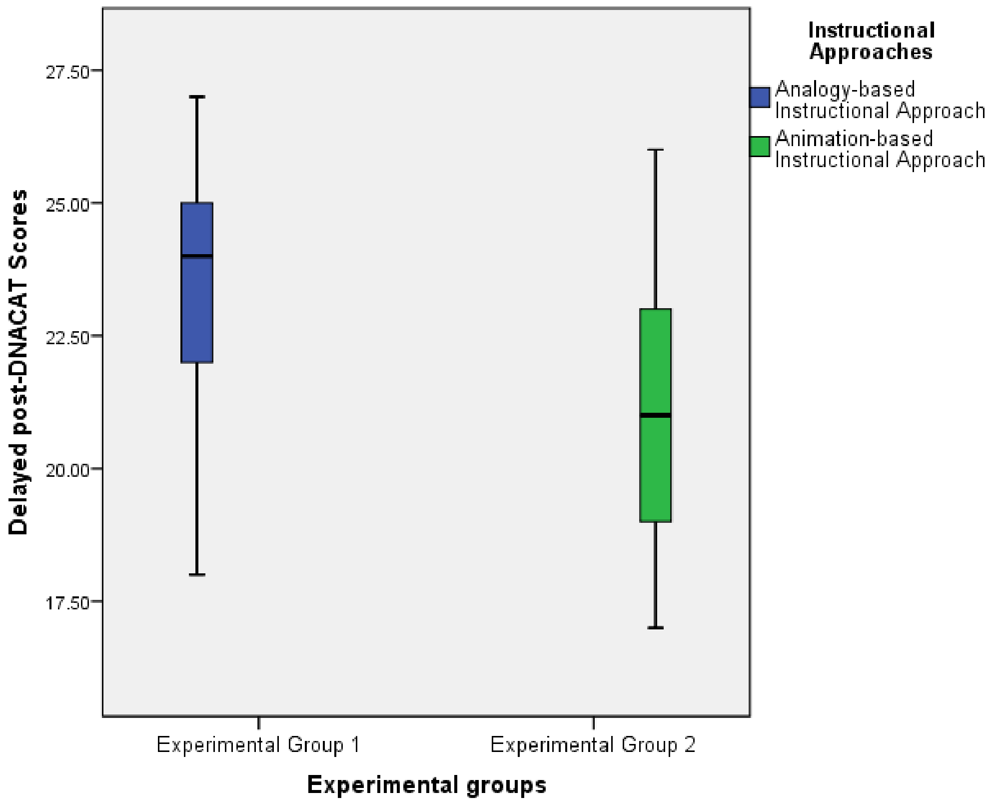

Figure 8: Comparing the Retention Ability of Analogy-based and Animation-based Instructional Groups using the Delayed Post-DNACAT Scores

From Figure 8, it can be realized that the analogy-based instructional group did better than the animation-based instructional group in the retention of the DNA structure and replication, transcription and translation concepts. For instance, it can be observed from the box plot that the minimum score the students in the analogy-based instructional group obtained from the retention test (delayed post-DNACAT) was 18 which is higher than the minimum score in the animation-based instructional group, which was 17. It can also be seen from the box plot that the median score the students in the analogy-based instructional group obtained from the retention test was 24 which is higher than the median score obtained in the animation-based instructional group, which was 21. Again, the maximum score the students in the analogy-

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based instructional group obtained from the retention test (delayed post-DNACAT) was 27 which is higher than the maximum score obtained in the animation-based instructional group, which was 26. It is therefore plausible to conclude that students' retention in the analogy-based instructional group was significantly higher than their retention in the animation-based instructional group.

This means that when analogy-based instructional approach is effectively used, it could improve students' retention more than the animation-based instructional approach in the DNA structure and replication, transcription and translation concepts.

4.2 Discussion of the Results

This section discusses the results or findings of the study in relation to the purpose of the study, which is comparing the effectiveness of analogy-based instructional approach and animation-based instructional approach on students' cognitive achievement (academic performance and retention) in the DNA structure and replication, transcription and translation concepts. The discussion is also based on syntheses of the findings, assertions of the literature, the research questions and the objectives of the study.

4.2.1 The effect of analogy-based instructional approach on students' performance in DNA concepts

The findings of this study proved that there is a significant difference between the pretest and posttest mean scores of the students in the analogy-based instructional group ($p<0.01$). That is, the students' performance was massively improved when taught with analogy-based instructional approach (treatment) compared to when taught with the conventional lecture-

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based instructional approach (prior to treatment). This implies that teaching with analogies has a positive effect on students' understanding and that teaching with analogies is an effective method for higher learning achievement. The reason for the difference in the achievement 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, 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 are able to convert abstract knowledge into concrete knowledge and therefore overcome alternative conceptions. This finding is in line with the findings of Ayanda, Abimbola and Ahmed (2012), Chiu and Lin (2005), Harrison and De Jong (2005), Nawaf (2016), and Owolabi (2007). The finding of Ayanda, Abimbola and Ahmed (2012) on the effects of teachers' use of analogies on the achievement of Senior School Biology Students at Oro in Kwara State of Nigeria indicated that the experimental group exposed to analogies significantly performed better over the control group exposed to the conventional method. Owolabi (2007) reported that teaching-with-analogy can clarify students doubt on specific information regarding scientific concepts, thus leading to better performance and retention of concepts compared to the lecture method. Nawaf (2016) also examined the effectiveness of analogy instructional strategy on undergraduate students' acquisition of organic chemistry concepts in Mutah University, Jordan. The results showed that there is significant difference in achievement between those students taught using analogy instructional strategy and those who were taught using traditional method in favour of the analogy instructional group. The finding of Harrison and De Jong (2005) also emphasized that

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analogies support meaningful learning and help students to construct complicated and abstract concepts easily. The finding of Orgill and Bodner (2004) suggests that analogies not only help students to become conscious of their own alternative conceptions, but also enable them to refute their alternative conceptions and accept scientific ideas which then facilitate learning of scientific concepts.

4.2.2 The effect of animation-based instructional approach on students' performance in DNA concepts

From the findings in Table 5, and Figure 6, the study revealed that students in animation-based instructional groups recorded statistically significant higher mean score in their post-test than their pre-test. This means that academic performance of the students improved after been exposed to the treatment (animation-based instructional approach). This may be as a result of the change in mode of instructions that is from teacher-centered (i.e. conventional lecture-based instructional approach) to students-centered (i.e. animation-based instructional approach). It was also observed that the use of instructional movies, animations and pictures give the learners the chance of learning the DNA concepts through more senses than just hearing about the concepts. The visual presentation of the DNA concepts strengthens students' understanding of the concepts by considerably reducing or eliminating abstraction. This greater conceptual understanding accounts for the higher mean score (achievement) of the students in their post-test application over their pre-test application. This finding is supported by the findings of Ayotola and Abiodun (2010), Rotbain, Marbach-Ad and Stavy (2008), Stith (2004), Tayo, (2012), Thomas and Israel (2014), and Yusuf and Afolabi (2010). Tayo, (2012)'s finding revealed that students exposed to developed animated agricultural package performed significantly better than those exposed to the conventional lecture method. In

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addition, Rotbain, Marbach-Ad and Stavy (2008) studied on the use of a computer animation to teach High School Molecular Biology. The finding shown that is the students in the computer animation group significantly outperformed the control group on a content knowledge measure. The differences were highly significant across all the three subtopics examined: structure of DNA and RNA; the conceptual relations between genetic material and product; the molecular processes: replication, transcription and translation. This finding again support the work of Thomas and Israel (2014) on effectives of animation and multimedia teaching on students' performance in science subjects. The finding revealed that there is significant difference in the academic achievement of students exposed to animation-based instructional approach over the lecture method.

4.2.3 Comparing the effectiveness of analogy-based and animation-based instructional approaches on students' performance in DNA concepts

The result of this study indicated that there was no significant difference between the two instructional groups in the overall students' performance ($t = 1.746$, $p = 0.085$; $Z = 1.74$, $p = 0.082$). That is, the performance of the students who received instruction in both analogy-based instructional approach and animation-based instructional approach improved significantly with large effect size. Though, this study did not indicate any significant difference in the overall performance of the students taught with analogy-based and animation-based instructional approaches, it was evidenced that the use of analogy-based instructional approach made students in that group perform better than their colleagues taught with animation-based instructional approach in all the three cognitive levels: knowledge, comprehension and application levels with statistically significant difference in the application level (application questions) ($t = 1.044$, $p = .005 < .05$)

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That is, analogy-based instructional approach improved the students' ability to answer the application questions more than the animation-based instructional approach. The reason to this improved achievement in the application concepts (questions) among the analogy-based instructional group could be because the lesson was based on the use and thinking of related analogies from their surroundings or examples from their previous experience (e.g. "*building a house"* analogy used in this study). The effort of the students to think of related analogies from their surroundings or examples from their previous experience seemed to align more logically with constructivism which emphasised the importance of involving students' pre-existing knowledge makes learning more meaningful (Haglund and Jeppsson, 2012).

This finding is in agreement with the findings of Dilber and Duzgun (2008), Guerra Ramos (2011), Marcelos and Nagem (2010), Paris and Glynn, (2004), and Sarantopoulos and Tsaparlis (2004). In their findings, they all indicated that analogy-based instruction has the capacity to help students in the comprehension and application of scientific concepts especially the abstract concepts. That is, analogy-based instructional approach has significantly positive effect on students' performance in comprehension and application type questions.

However, this finding somehow contradicts the finding of Uzma (2016) on "effectiveness of animation-based and analogy-based instructions on Tenth-Grade Students' Achievement in Chemistry in Kishanganj, Bihar, India. Though the Uzman's study was on Chemistry and used" The *Soccer Analogy for Weak and Strong Acids and Bases"*, the finding from the analysis of covariance (ANCOVA) showed that Traditional Teaching supplemented with Computer Animations (TTCA) was more effective in enhancing the students' achievement in acids and bases in Chemistry than Traditional Teaching supplemented with Analogy (TTA).

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4.2.4 Comparing the effectiveness of analogy-based and animation-based instructional approaches on students' retention in DNA concepts

The result presented in Tables 8 and 9 revealed that there is a significant difference in the delayed-posttest mean scores (retention test scores) of biology students exposed to analogy-based instructional approach in DNA structure and replication, transcription and translation concepts and their counterparts exposed to animation-based instructional approach. The significant difference is in favor of the students exposed to analogy-based instructional approach as revealed in their mean scores and the *F*-value in Tables 8 and 9 respectively. This might be due to 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, enabling them to develop a more scientific understanding of the concept. These aid the memory retention resulting in higher performance of the students taught with analogy-based instructional approach. Also, the researcher believe that this process of establishing associations with elements, events and processes in the environment helped students in the analogy-based instructional group to expand their mental networks and recall the information longer than the animation-based instructional group. Again, the construction of visual associations and mental models during the analogy-based instruction should have played an essential role in helping students in the analogy-based instructional group to preserve the information they learnt for longer period. In addition, the verbal and visual links made the target concept better represented in students' memories and therefore better enhanced retention of the concept among the students' taught with analogy-based instructional approach. This finding is in concurrence or in line with the findings of Mangal (2011),

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Owolabi (2007), and Paris and Glynn (2004). Owolabi (2007) reported that teaching-with-analogy can clarify students doubt on specific information regarding scientific concepts, thus leading to better performance and retention of concepts. Mangal (2011) ascertained that retention of learned material can be improve through association of ideas, connection, and systematic thinking in the task of recall. Study by Paris & Glynn (2004) claimed that, the verbal and visual links in the analogy-based instruction made the target concept better represented in students' memories and therefore better enhanced retention of concepts.

4.3 Implications of the Study Findings for Science Education

The findings of this study have educational implications for students, teachers and the Ministry of Education. The findings of this study provide useful feedback on the comparative effectiveness of analogy-based instructional approach, animation-based instructional approach and conventional lecture-based instructional approach as effective instructional delivery approach and therefore provide the basis upon which biology teachers could build to enhance the efficacy of their instructional delivery approach in teaching. In general, the study revealed that analogy-based instructional approach was more effective followed by animation-based instructional approach with conventional lecture-based instructional approach been least effective in relation to students' achievement and retention of DNA structure and replication, transcription and translation concepts. That is, results from this study shown that students taught using analogy-based instructional approach achieved higher and retained more knowledge of the DNA structure and replication, transcription and translation concepts in biology. The relative effectiveness of analogy-based instructional approach to massively improve the students' achievement and retention of the concept could be as a result of its ability to enhance students' visualization and reorganization of abstract biological concepts in

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their cognitive structure. Again, the construction of visual associations and mental models during the analogy-based instruction should have played an essential role in helping the students in the analogy-based instructional group to preserve the information they learnt for longer period.

Classroom learning is enhanced by an instructional delivery approaches that are more innovative and student-centered, such as analogy-based instructional approach. Therefore biology teachers have a major role in introducing the use of the analogy-based instructional approach as part of their teaching approach in teaching abstract and difficult concepts. The use of this instructional delivery approach may not necessarily be limited to enhancement of achievement and retention, but may also arouse students' interest, curiosity, motivation, imagination and stimulation which could lead to retention and permanent learning in students. It is therefore, paramount for the Ministry of Education to introduce this instructional delivery approach into the school curriculum and encourage its utilization. Finally, to build up the literature on analogy-based instructional approach with aim of enhancing students' performance and retention in molecular and other abstract and difficult concepts in biology, there is the need to verify this findings through the use of randomly selected large sample size participants.

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CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

5.0 Overview

This chapter presents the summary of the study in general. It gives the summary of the findings that emerged from the data collected. Conclusions are then drawn from the findings. Recommendations are made on the basis of the findings and conclusions. It also gives suggestions for further research.

5.1 Summary of the Study

The principal focus of the study was to investigate the comparing effect of the extent to which analogy-based and animation-based instructional approaches influence senior high school students' cognitive achievement (academic performance and retention) in deoxyribonucleic acid (DNA) concepts especially in DNA structure and replication, transcription and translation concepts. Four research questions with two hypotheses guided the study and tested at 0.05 level of significance.

Related literature was reviewed. The review showed among other things that some studies had been carried out using analogy-based instructional approach, while others were carried out using animation-based instructional approach but only one compared the two together, which was even in the area of chemistry.

A quasi-experimental design was used. Seventy-nine (79) second year senior high school general science students from two schools (Boakye-Tromo Senior High/Technical School (n=39) and Yamfo Anglican Senior High School (n=40) in Tano North Municipal, of Brong Ahafo Region were purposively sampled and used. DNA Concept Achievement Test

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(DNACAT) with a reliability coefficient of 0.88 was used to measure students' achievement and retention before and after treatment. Data obtained were analysed using various statistics including mean, standard deviation, Wilcoxon signed rank test, Mann-Whitney test, paired sampled *t*-test, independent sample *t*-test, Cohen *d* effect size and one way analysis of covariance (ANCOVA) at 0.05 level of significance to answer the research questions and hypotheses. Computation for the above-mentioned methods of data analyses were done using statistical package for social sciences (SPSS) version 20. Pictorially, box plot was used to present the data.

Findings indicated that, students who were taught the concepts using analogy-based instructional approach achieved and retained better that those taught using animation-based instructional approach. The educational implications of the findings were highlighted. It was recommended amongst other things, that Ministry of Education should incorporate analogy-based instructional approach in the school curriculum at all levels and also encourage the biology teachers to use this approach in biology classroom especially when teaching and learning molecular and other abstract biological concepts in order to achieve optimum student learning. The limitation of the study was highlighted and suggestions for further research made. Based on the findings of this study, it was concluded that analogy-based instructional approach was more effective in enhancing senior high school students' achievement and retention in DNA concepts such as DNA structure and replication, transcription and translation concepts.

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5.2 Major Findings

1. The study proved that there was a significant difference between the pretest and posttest mean scores of the students in the analogy-based instructional group ($p<0.01$). That is, the students' performance was massively improved when taught with analogy-based instructional approach (treatment) compared to when taught with the conventional lecture-based instructional approach (prior to treatment) ($t = 18.29$, $p < 0.001$; $Z = 5.53$, $d = 2.98$).
2. The study revealed that students in animation-based instructional groups recorded significantly higher mean score in their post-test (after the treatment) than their pre-test (prior to treatment). This implied that students performed tremendously better when taught with the animation-based instructional approach (treatment) compared to when taught with conventional lecture-based instructional approach ($t = 16.98$, $p < 0.001$; $Z = 5.62$, $d = 2.53$).
3. It was found that there was no significant difference in the mean performance scores (post-DNACAT scores) between the two instructional (experimental) groups in terms of two cognitive levels: knowledge and comprehension, although the analogy-based instructional group had the higher post-test mean scores in all the two cognitive levels (knowledge: $\bar{x} = 8.95$, SD = 0.99 and comprehension: $\bar{x} = 10.62$) compared to the animation-based instructional group (knowledge: $\bar{x} = 8.73$, SD = 0.91 and comprehension: $\bar{x} = 10.35$, SD = 0.98). However, students taught with analogy-based instructional approach significantly outperformed the students taught with animation-based instructional approach in the application questions of the post-DNACAT (post-test) ($t = 1.044$, $p = 0.005 < .05$, $d = 0.63$). Again, there was no significant difference between the two instructional groups in the overall total score of the post-DNACAT

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(post-test) (t = 1.746, p = 0.085 >0 .05; Z = 1.74, p = .082), but the analogy-based instructional group had the higher mean achievement score with lower standard deviation ($\bar{x}$ = 27.13, SD = 2.39) compared to the animation-based instructional group ($\bar{x}$ = 26.15, 2.59) in the overall total score of the post-test (post-DNACAT) though not significant.

4. The study revealed that there is a significant difference in the delayed-posttest mean scores (retention test scores) between the students exposed to analogy-based instructional approach and animation-based instructional approach in the DNA concepts. The difference is in favor of the students exposed to analogy-based instructional approach (F [2, 76] =19.82, p < 0.001, η_p^2 = 0.21).

5.3 Conclusion

Based on the findings of this study, the following conclusions were drawn:

- Students from Boakye Tromo Senior High/Technical School who were taught the DNA concepts using analogy-based instructional approach performed better academically than when they were taught with conventional lecture-based instructional approach.
- Students from Yamfo Anglican Senior High School who were taught the DNA concepts using animation-based instructional approach performed better academically than when they were taught with conventional lecture-based instructional approach.
- Students from Boakye Tromo Senior High/Technical School who were taught the DNA concepts using analogy-based instructional approach achieved better in application questions than those from Yamfo Anglican Senior High School who were taught the concepts with animation-based instructional approach.

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- Boakye Tromo Senior High/Technical School Students exposed to analogy-based instructional approach exhibited high level of retention in DNA concepts than those from Yamfo Anglican Senior High School exposed to animation-based instructional approach.

In conclusion, analogy-based instructional approach has the higher potential of enhancing Tano North Senior High School Students' especially Boakye Tromo Senior High/Technical School Students' academic performance and retention in DNA structure and replication, transcription and translation concepts.

5.4 Recommendation

- Heads of Senior High Schools as while as Heads of Science Departments in the Tano North Municipality should encourage and emphasize the use of analogy-based instructional approach during biology lessons especially during DNA concepts lessons by biology teachers, particular those at Boakye Tromo Senior High/Technical School.
- Since analogy-based instructional approach has been found to enhance Boakye Tromo Senior High/Technical School Students' visualization and reorganization of abstract biological concepts in their cognitive structure and improved their achievement and retention scores in the DNA concepts, biology teachers should therefore be encouraged to employ it more in the teaching of biology especially for concepts that are abstract or difficult instead of the conventional lecture method in the school as while as other Senior High Schools within the Municipality.
- It is in teacher training institutions that future teachers learn relevant content and pedagogical knowledge. It is therefore important to incorporate analogy-based instruction into teacher education curriculum and be taught as other teaching methods

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are being taught, so as to popularize its use among teachers and hence bring about more effective learning of abstract and molecular biological concepts and biology as a whole in the senior high schools.

- Biology Teachers at Boakye Tromo Senior High/Technical School should select analogies that are familiar to students because such analogies should eliminate and avoid misconceptions, motivate students, avoid time wastage and easy to use by the teachers.
- Biology textbook authors within the Tano North Municipality should be encouraged to include enriched analogies in their texts for easy access for students and teachers. Using enriched analogies means the author should indicate the limitations of the analogies (where the analogies break).
- The Schools, Municipal Education Directorate and the Municipal Assembly as while as other educational stakeholders in the Tano North Municipal should sponsor further researches on the effectiveness of the analogy-based instructional approach in promoting performance and retention in other molecular concepts and the entre biology topics in Senior High Schools biology.

5.5 Suggestions for further Research

- This study should be replicated by increasing the number of schools and classes which are participating in order to increase generalizability and make it more concrete.
- More work needs to be done by researchers to identify and generate more analogies that could be productively used and use them as the basis for teaching with analogy in biology within the Senior High Schools in the Tano North Municipal.

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- Similar studies should be conducted in other areas of biological molecular concept as well as other biology topics in all educational levels.
- Similar studies can be replicated in other subject areas like chemistry, physics, engineering and mathematics.
- Studies should be conducted to investigate the gender effect, interaction effect, interest, awareness and views of teachers and students on the use of analogy-based instructional approach in science classroom in Ghanaian context.

University of Education, Winneba http://ir.uew.edu.gh

REFERNCES

Abbas, P. (2012). The significant role of multimedia in motivating EFL learners' interest in English language learning. *Intentional Journal of Modern Education and Computer Science, 4*, 57-66.

Abimbola, I. O. & Mustapha, M. T. (2002). The use of analogies in communicating difficult science concepts to secondary school students. *Journal of Nigeria Teacher Today, 8*, 33-32.

Abrams, E., Southerland, S. A., & Cummins, C. C. (2001). The how's and why's of biological change: How students overlook the cause of phenomena in their search for meaning. *International Journal of Science Education, 23*(12), 1271–1281.

Adebayo, A. O. & Oladele, O. (2016). Effects of computer simulation instructional strategy on biology students' academic achievement in DNA replication and transcription. *Asian Journal of Educational Research, 4*(2), 16-24.

Adegoke A. B. (2010). Integrating animations, narratives and textual information for improving Physics learning. *Electronic Journal of Research in Educational Psychology*, *8*(2), 725-748.

Ainsworth, S. (2008). How do animations influence learning. In. D. Robinson & G. Schraw (Eds.), *Current perspectives on cognition, learning and instruction: Recent innovations in educational technology that facilitate student learning* (pp. 37-67). UK: Information Age Publishing.

Ajaja, P. O. (2013). Which strategy best suits biology teaching? Lecturing, concept mapping, cooperative learning or learning cycle? *Electronic Journal of Science Education, 17*(1), 1-22.

Akor S. T. (2011). *The use of computer aided instruction for the teaching and learning of electronics courses.* A seminar paper presented to the Department of Vocational Teacher Education. University of Nigeria, Nsuka on 16th July.

Akpinar, E., & Ergin, O. (2008). Fostering primary school students' understanding of cells and other related concepts with interactive computer animation instruction accompanied by teacher and student prepared concept maps. *Asia-Pacific Forum on Science Learning and Teaching, 9*(1). Retrieved January 1, 2018, from http://www.ied.edu.hk/apfslt/v9_issue1/akpinar/index.htm

Akubuilo, D. U. (2004). The effects of problem solving instructional strategies on students' achievement and retention in biology with respect to location in Enugu State. *Journal of Science Teachers Association of Nigeria, 39*(1&2), 94-100.

Aldağ, H., & Sezgin, M. E. (2002). Dual coding theory in multimedia applications. *Marmara Universitesi Ataturk Egitim Fakultesi Bilimleri Dergisi, 15,* 29-44.

Allan, G. H., & Treagust, D. F. (1993). Teaching about conduction using the domino analogy. *Paper presented at the Annual conference of the Australian Association Research in Education Fremantle, Western Australia*. pp. 22 – 25.

Al-Balushi, S. M. (2011). Students' evaluation of the credibility of scientific models that represent natural entities and phenomena. *International Journal of Science and*

University of Education, Winneba http://ir.uew.edu.gh

Mathematics Education, 9(3), 571-601. DOI: 510.1007/s10763-10010-19209-10764.

Al-Hinai, M., & Al-Balushi, S. (2015). Rectifying analogy-based instruction to enhance immediate and postponed science achievement. *Journal of Turkish Science Education, 12*(1), 11-18.

American Association for the Advancement of Science (2009). *Vision and change in undergraduate biology education a call to action*. Washington DC. Retrieved, August 12, 2017 from http://visionandchange.org/files/2011/03/Revised-Vision-and-Change-Final-Report.pdf

Ameyaw, Y. (2015). Improving teaching and learning of glycolysis and kreb's cycle using concept mapping technique. *International Journal of Sciences, 4(*6), 1-9. DOI:10.18483/ijSci.706. Retrieved, October 10, 2017 from http://www.ijsciences.com/pub/issue /2015-06/

Anderson-Inman, L., & Horney, M. (1996). Computer-based concept mapping: Enhancing literacy with tools for visual thinking. *Journal of Adolescent and Adult Literacy, 40*(4), 302-306.

Anderson-Inman, L., & Ditson, L. (1999). Computer-based concept mapping: A tool for negotiating meaning. *Learning and Leading with Technology, 26*(8), 6-13.

Anderson-Inman, L. & Zeitz, L. (1993). Computer-based concept mapping: Active studying for active learners. *The Computer Teacher, 27*(1), 6-11.

University of Education, Winneba http://ir.uew.edu.gh

Aninweze, C. A. (2014). *Effects of two instructional delivery approaches on senior secondary schools students' achievement and retention in Biology.* M.Ed. Thesis, University of Nigeria, Nsukka.

Ardac, D., & Akaygün, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representation on students' understanding of chemical change. *Journal of Research in Science Teaching*, *41*(4), 317-337.

Atadoga, M. M., & Lakpini, M. A. (2013). A comparison of numeracy achievement of primary school pupils taught using whole class and varied classroom organization instructions. *Proceedings of Multicultural African Conference, Held at Faculty of Education, Ahmadu Bello University, Zaria, between 11th – 15th June, 2013.*

Atılboz, N. G. (2004). Understanding of high school 1st grade students' level of understanding about mitosis and meiosis division and their misconceptions. *Journal of Gazi University Education Faculty, 24*(3), 147-157.

Aubusson, P. J., Harrison, A. G., & Ritchie, S. M. (Eds.). (2006). *Metaphor and analogy in science education.* Dordrecht, Netherlands: Springer.

Ayanda, M. O., Abimbola, I. O., & Ahmed, M. A. (2012). Effects of teachers' use of analogies on the achievement of senior school biology students in Oro, Kwara State, Nigeria. *Elixir Social Studies 47,* 8884-8888.

Aykanat, F., Doğru, M., & Kalender, S. (2005). The effect of science instruction by the computer-based concept maps method on the students' achievement, *Kastamonu Education Journal, 13*(2), 391-400.

University of Education, Winneba http://ir.uew.edu.gh

Ayotola, A., & Abiodun, S. (2010). Computer animation and the academic achievement of Nigerian senior secondary school students in biology. *Journal of the Research Center for Educational Technology*, *6*(2), 148-161.

Baker, W. P., & Lawson, A. E. (1995). *Effect of analogical instruction and reasoning level on achievement in general genetics*. Tempe, AZ: Department of Zoology. (ERIC Document Reproduction Service No. 390 713).

Bannon, B. O., (2012). *Planning for instruction: Instructional methods.* Retrieved September 1, 2017 from Http://edtech2.tennessee.edu/projects/bobannon.

Barak, M., Ashkar, T., & Dori, Y. J. (2010). *Teaching science via animated movies; Its effect on students learning outcomes and motivation.* Proceedings of the Chais Conference on Instructional Technologies Research. The Open University of Israel. Retrieved December 17, 2017 from http://telem-pub.openu.ac.i/users/chais

Berlongieri, R. L. (2013). *Teaching standards*: *Instructional delivery approach*. Vandercook College of music.

Bhatti, U., Shaikh, R. S., Rehman R., Memon Q. M., & Buleidi A. J. (2015). Chalk and board versus animation based learning. *Pak. J. of Physiol., 11*(1), 20–33.

Bhoopatiraj, C. & Chellamani, K. (2013). Analysis of test items on difficulty level and discrimination index in the test for research in education. *IRJC 2*(2), 189-93.

Bichi, S. (2002). *Effects of problem solving strategy and enriched curriculum on students‘ achievement in evolution concepts among secondary school students.* Unpublished Doctoral Dissertation. Ahmadu Bello University, Zaria, Nigeria.

University of Education, Winneba http://ir.uew.edu.gh

Biddix, J. P. (2009). Research Methods. *Uncomplicated reviews of educational research methods.* Retrieved November 15, 2017, from http//:wwwresearchrundowns.wordpress.com

Brown, D. E. (1992). Using examples and analogies to remediate misconceptions in physics: Factors influencing conceptual change. *Journal of Research in Science Teaching, 29,* 17–34. doi:10.1002/tea.3660290104

Brown, D. E. & Clement, J. (1987). Overcoming misconceptions via analogical reasoning: Abstract transfer versus explanatory model construction. *Instructional Science, 18*(4), 237–261.

Brown, S., & Salter, S. (2010). Analogies in science and science teaching. *Advances in Psychological Education, 34*(1), 167-169. doi:10.1152/advan.00022.2010.

Bruner, J. S. (1960*). The process of education*. New York: Alfred A. Knop Inc.

Bukova-Güzel, E., & Cantürk-Günhan, B. (2010). Prospective mathematics teachers' views about using flash animations in mathematics lessons. *International Journal of Human and Social Sciences Volume: 5*(3), 54-159.

Burton, L. J., & Mazerolle, S. M. (2011). Survey instruction validity part I: Principles of survey instruction development and validation in athletic training education research. *Athletics Training Education journal, 6*(1), 27-35.

Busari, A. T. (2009). Field study in geography, an inevitable tool for acquiring observatory and analytical skills. *Informational Journal of Research in Education. 6,* (1&2).

University of Education, Winneba http://ir.uew.edu.gh

Caleb, F. D. (2016). Comprehensive molecular characterization of clear cell renal cell carcinoma. *New England Journal of Medicine, 374*(2), 135-145.

Calik, M. & Kaya, E. (2012). Examining analogies in science and technology textbooks and science and technology curriculum. *Elementary Education Online, 11*(4), 856-868.

Campbell, N. A., & Reece, J. B. (2002). *Biology*, (6th ed). San Francisco, CA: Pearson Education.

Carey, S. (1986). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Çelik, E. (2007). *The effect of using computer aided animations to geography teaching skills of secondary education.* Unpublished Master's Thesis. Marmara University Social Science Institute, İstanbul.

Cepni, S., Tas. E., & Kose, S. (2006). The effects computer-assisted material on students' cognitive levels, misconceptions and attitudes towards science. *Computers and Education*, *46*, 192-205.

Chew, F. T. (2004). *Use of analogies to teach general biology to non-biology majors.* Retrieved September 9, 2017 from http://.www.edt/.nus.edu.sg/link/mar2004/tm3 htm.

Chianson, M. M (2008). *Effects of cooperative learning on students' achievement and retention in circle geometry in secondary schools in Benue State*. Unpublished M.Ed. Thesis, Benue State University, Markurdi.

University of Education, Winneba http://ir.uew.edu.gh

Ching, Y., Ke, F., Lin, H., & Dwyer, F. (2005). Effects of animation in facilitating student achievement: A meta-analytic assessment. In P. Kommers & G. Richards (Eds.), *Proceedings of the world conference on educational multimedia, hypermedia and telecommunications* (pp. 4459-4461). Chesapeake, VA: AACE. Retrieved November 29, 2017, from http://www.editlib.org/p/20779.

Chowdhury, P. (2015). Analogy as a child centric approach to teach: As seen by a high school teacher. *European Journal of Educational Sciences, 2*(3), 1857- 6036.

Christine, A. (2013). *The American heritage dictionary of idioms*. Houghton Mifflin Harcourt.

Chuang, Y. R. (1999). Teaching in a multimedia computer Environment: A study of the effects of learning style, gender and math achievement. *Interactive Multimedia Electronic Journal of Computer – Enhanced Learning.* Retrieved December 15, 2000, from http://ime.wfu.edu/articles/1999/1/10/index.asp

Chiu, M. N., & Lin, J. W. (2005). Promoting fourth graders' conceptual change of their understanding of electric current via multiple analogies. *Journal of Research in Science Teaching, 42*(4), 429-464.

Clark, R. C. & Mayer, R. E. (2003). *E-learning and science of instruction*. NY: Pfeiffer.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching, 30,* 1241–1257.

University of Education, Winneba http://ir.uew.edu.gh

Clement, J. (2003). *Abduction and analogy in scientific model construction.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Coll, R. K., France, B., & Taylor, I. (2005). The role of models and analogies in science education: Implication from research. *International Journal of Science Education, 27*(2), 183-198. DOI: 10.1080/0950069042000276712

Coll, C., Rochera, M. J., Mayordomo, R. M., & Naranjo, M. (2007). Continuous assessment and support for learning: An experience in educational innovation with ICT support in higher education. *Electronic Journal of Research in Educational Psychology*, *7,* 369 – 396.

Cope, S. G. (2011). The types of teaching strategies. Retrieved November 8, 2017, from http://www.ehow.com/info_12044336_types_teaching_strategies.

Corcoran, T. & Silander, M. (2009). Instruction in High School: The Evidence and the Challenge. *Journal of America's High Schools, 19*(1), 38-39.

Cox, M. M., & Nelson, L. D. (Eds). (2000). *Learning Principles of Biochemistry.* Retrieved November 17, 2017 from https://www.researchgate.net/publication/483 76766. doi:10.007/978-3-662-08289-8

University of Education, Winneba http://ir.uew.edu.gh

Creswell, J. W. (2002). *Educational Research: Planning, conducting, and evaluating quantitative and qualitative research*. Upper Saddle River, NJ: Merrill Prentice Hall.

Dagher, Z. R. (1994). Does the use of analogies contribute to conceptual change? *Science Education, 78*(6), 601–614.

Daşdemir, İ., (2006). *The effect of use animation on students' academic achievements and retentions in primary science course.* Unpublished Master's Thesis. Atatürk University Graduate School of Natural and Applied Sciences, Erzurum.

Daşdemir, İ., & Doymuş, K. (2012). The effect of using animation on students' achievement, permanent of the learned information and science process skills at "force and motion" unit of 8th class. *Journal of Research in Education and Teaching, 1*(1), 77-87.

Dilber, R., & Duzgun, B. (2008). Effectiveness of analogy on students' success and elimination of misconceptions. *Latin American Journal of Physics Education, 2*(3), 147- 183.

Donelly, C. M., & McDaniel, M. A. (1993). Use of analogy in learning scientific concepts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 975-987.

Duit, R., Roth, W. M., Komorek, M., & Wilbers, J. (2001). Fostering conceptual change by analogies between Scylla and Charybdis. *Learning and Instruction, 11*, 283-303.

University of Education, Winneba http://ir.uew.edu.gh

Dunican, E. (2002). *Making the analogy: Alternative delivery techniques for first year programme courses.* Retrieved December 27, from www.ppig.org

Duncan, G. R., & Reiser, B. J. (2007). Reasoning across ontologically distinct levels: Students' understandings of molecular genetics. *Journal of Research in Science Teaching, 44*(7), 938-959

Dzidzinyo, A. F., Bonney, E. A., & Davis, G. (2014). An investigation into weakness exhibited by senior high school biology students in graph work in the cape coast metropolis of Ghana. *Elixir Education Technology, 72*, 25677-25686.

Ebenezer, J. V. (2001). A hypermedia environment to explore and negotiate students' conceptions: Animation of solution process of table salt. *Journal of Science Education and Technology, 10*(1), 73-92.

Echija, E. C., Bayquen, C. V., Alfonzo, R. L., & De Vera, E. A. (2003). *Science and technology for the future III*. Makati City: Diwa Scholastic Press.

Educational Encyclopedia (2013). Individualized instruction pace, methods and content. < a href=" http://education.state university.com/pages/2085/individualizedinstruc tion.html".>

Elmstrom, K. (2011). *Computer animation in teaching science: Effectiveness in teaching retrograde motion to 9th graders* (Unpublished Doctoral Dissertation). University of Rhode Island.

University of Education, Winneba http://ir.uew.edu.gh

Ekici, E., & Ekici, F. (2011). New and effective way to utilization of information technologies in science education: Slow motion animations. *Elementary Education Online, 10*(2), 1-9.

Etukudo, U. E. (2006). The Effect of Computer Assisted Instruction on Gender and Performance of Junior Secondary School in Mathematics. *ABACUS Journal of Mathematical Association of Nigeria, 27*(1), 1-8.

Federal Ministry of Education, Science and Technology (2001). *A Handbook on Continuous Assessment.* Ibadan: Heinemann Educational Books.

Fong, S. F. (2000). *Kesan Animasi Terhadap Pembelajaran Pengetahuan Prosedur Meiosis di Kalangan Pelajar Pelbagai Profil Psikologi.* Tesis Doktor Falsafah (Tidak diterbitkan). Universiti Sains Malaysia: Pulau Pinang.

Gabel, D. L. (2003). Enhancing the conceptual understanding of science. *Educational Horizons 81*(2), 70–76.

Garcia-López, M. N., & Romero, I. M. (2009). The influence of new technologies on learning and attitudes in mathematics in secondary students. *Electronic Journal of Research in Educational Psychology*, *5,* 783 – 804.

Gbamanja, S. P. T. (1991). *Modern Methods in Science Education in Africa*. Abuja: Totan Publishers Ltd.

Genc, M. (2013). The effect of analogy-based teaching on students' achievement and students' views about analogies. *Asia-Pacific Forum on Science Learning and Teaching, 14*(2), 21-29.

University of Education, Winneba http://ir.uew.edu.gh

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7,* 155-170.

Gentner, D., Brem, S., Ferguson, R., Markman, A., Levidow, B., Wolff, P., & Forbus, K. (1997). Analogical reasoning and conceptual change: A case study of Johannes Kepler. *The Journal of the Learning Sciences, 6*(1), 3-40.

Geraldine, E. I. (2000). *Undergraduate student attitude and acceptance of computer enhanced instruction in a college nutrition course.* Master's Thesis, University of Wisconsin-Stout. Retrieved October 5, 2017 from http://www2.uwstout.edu/conte nt /lib/thesis/2000/2000iwanskig.pdf

Gholami, E., Panahi, K. M. K., Neghad, R. A. S., & Heidari, M. (2007). Relationship of academic achievement and self-concept with academic achievement thought eighth grade students in science lessons based on analysis of results. *Journal of Iranian Psychologists*, 7, 207-218

Gil, V. M. S., & Paiva, J. C. M. (2006). Using computer simulations to teach salt solubility. *Journal of Chemical Education, 83*(1), 170-174.

Gilbert, S. F. (2003). The genome in its ecological context: philosophical perspectives on interspecies epigenesis. *Journal of the New York Academy of Science, 981*, 202-218.

Glynn, S. M. (1991). Explaining science concepts: A teaching-with-analogies model. In S. M. Glynn, R. H. Yeany & B. K. Britton (Eds.). *The psychology of learning science*. Hillsdale, NJ: Erlbaum.

University of Education, Winneba http://ir.uew.edu.gh

Glynn, S. M. (2007). Methods and strategies: The teaching-with-analogies model. *Science and Children*, *44*(8), 52–55. Retrieved October 10, 2017 from www.nsta.org/publications/news/story.aspX?ids53640

Glynn, S. M., & Takahashi, T. (1998). Learning from analogy-enhanced text. *Journal of Research in Science Teaching, 35*, 1129-1149.

Gobert, D. J., O'Dwyer, L., Horwitz, P., Buckley, B. C., Levy, S. T., & Wilensky, W. (2011). *International Journal of Science Education, 33*, 653-684.

Gökhan, A. (2011). *The effect of animation on academic achievement of the greenhouse gas effect, acid rain and depletion of ozone layer topics in secondary education* Unpublished Master's Thesis. Çukurova University, Institute of Social Science, Computer and Instructional Technology Department, Adana.

Gongden, E. J. (2016). Comparative effects of two metacognitive instructional strategies on gender and students' problem-solving ability in selected chemistry concepts. *International Journal of Innovative Research & Development, 5*(4), 110-121.

Guerra-Ramos, M. (2011). Analogies as tools for meaning making in elementary science education: How do they work in classroom settings? *Eurasia Journal of Mathematics, Science & Technology Education, 7*(11), 29-39.

Gulfidan, C., & Bryan, N. (2003). *The effect of unrelated domain analogies on the application performance of newly acquired knowledge*. Retrieved November 2, 2017 from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.195.628&rep=rep1&type=pdf

University of Education, Winneba http://ir.uew.edu.gh

Güvercin, Z. (2010). *Effect of simulation assisted software in Physics course on academic achievement, attitude and retention of the students*. Unpublished Master's Thesis, Çukurova University, Social Sciences Institute, Adana.

Guzman, K., & Bartlett, J. (2012). Using simple manipulative to improve student comprehension of a complex biological process. *Biochemistry and Molecular Biology Education, 40*(5), 320-327.

Haglund, J., & Jeppsson, F. (2012). Using self-generated analogies in teaching of thermodynamics. *Journal of Research in Science Teaching, 49*(7), 898-921.

Hall, T. (2012). Digital renaissance: The creative potential of narrative technology in education. *Creative Education, 3,* 96-100. doi:10.4236/ce.2012.31016

Harrison, A. G. (2001). How do teachers and textbook writers model scientific ideas for students? *Research in Science Education, 31*, 401-436.

Harrison, A. G., & De Jong, O. (2005). Exploring the use of multiple analogical models when teaching and learning chemical equilibrium. *Journal of Research in Science Teaching, 42*, 1135-1159.

Harrison, A. G., & Treagust, D. F. (1993). Teaching with analogies: A case study in grade-10 optics. *Journal of Research in Science Teaching, 30*(10), 1291-1307.

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education, 22*(9), 1011-1026.

University of Education, Winneba http://ir.uew.edu.gh

Harrison, A. G., & Treagust, D. F. (2006). Teaching and learning with analogies. In P. Aubusson, A. G. Harrison, & S. Ritchie (Eds.), *Metaphor and analogy in science education* (pp.11-24). Netherlands: Springer.

Harrison, A. G., & Coll., R. K. (Eds.). (2008). *Using analogies in middle and secondary science classrooms.* Thousand Oaks, CA: Corwin Press.

Hasler, B. S. (2007). Learner control, cognitive load and instructional animation. *Appl. Cognit. Psychol. 21*, 713-729.

Hewitt, P. G. (2002). Conceptual Physics, 9th Ed. Menlo Park, CA: Addison-Wesley Publishing.

Hibbing, A. N., & Rankin-Erickson, J. L. (2003). A picture is worth a thousand words: Using visual images to improve comprehension for middle school struggling readers. *Reading Teacher, 56*(8), 758-770.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem based and inquiry learning. A response to Kirschner, Sweller and Clark (2006). *Educational Psychologist*, *42*(2c), 99-107.

Hoban, G., Loughran, G., & Nielsen, W. (2011). Slow motion: Pre service elementary teachers representing science knowledge through creating multimodal digital animations. *Journal of Research in Science Teaching, 48*(9), 985-1009.

Hoffler, N. T., & Leutner, D., (2007). Instructional animation versus static pictures: A meta–analysis. *Learning and Instruction, 7*(1), 722–738. Retrieved December 29, 2017 from http:/www.sciencedirect.com on 23/02/2014.

University of Education, Winneba http://ir.uew.edu.gh

Holyoak, K. J. (2012). *Analogy and relational reasoning*. In K. J. Holyoak & R. G. Morrison (Eds.), The Oxford handbook of thinking and reasoning (pp. 234-259). New York: Oxford University Press.

Holyoak, K. J., & Thagard, R. (1995). *Mental leaps: Analogy in creative thought.* Cambridge, MA: MIT Press.

Hornby, A. S. (2001). *Oxford Advanced Learners' Dictionary of Current English.* Italy: Oxford University Press.

Hotiu, A. (2006). *The relationship between item difficulty and discrimination indices in multiple-choice tests in a physical science course*. MSc thesis. Boca Raton, Florida: Florida Atlantic University. Retrieved January 5, 2018 from http://www. physics.fau.edu/research/education/A.Hotiu_thesis.pdf

Huddle, A. P., White, W. M., & Rogers, F. (2000). Simulations for teaching chemical equilibrium. *Journal of Chemical Equilibrium*, *77*(7), 920-926.

Ifeyinwa, N. O. (2009). *Effect of learning activity package (LAP) on students' achievement and retention in senior secondary school Biology*. Doctoral Thesis, University Of Nigeria, Nsukka. Retrieved December 7, 2016, from http://www.unn.edu.ng/publications/files/images/NEBOH,%20OLIVE%20IFEYINWA.pdf

Iji, C. O. (2002). *Effects of logo and basic programmes on achievement and retention in geometry of junior secondary school students*. Unpublished Ph.D. Thesis, University of Nigeria, Nsukka.

University of Education, Winneba http://ir.uew.edu.gh

Ijioma, B. C., & Onwukwe E. O. (2011). Using culturally-based analogical concepts in teaching secondary school science: Model of a lesson plan. *International Journal of Science and Technology Education Research*, *2*(1), 1 – 5. Retrieved November 27, 2017 from http://www.academicjournals.org/IJSTER ISSN2141-6559

International Council for Science (2002). Report of the scientific and technological community to the world summit on sustainable development. *Report no. 1.*

Iravani, R. M., & Delfechresh, H. (2011). Effect of CAI on science achievement of higher primary students. *International Journal of Business and Social Science*, *2*(19), 70-72.

Iskander, W., & Curtis, S. (2005). Use of colour and interactive animation in learning 3D vector. *The Journal of Computer in Mathematics and Science Teaching, 24*(2), 149-156.

James, M. C., & Scharmann, L. C. (2007). Using analogies to improve the teaching performance of preservice teachers. *Journal of Research in Science Teaching*, *44*(4), 565-585.

Jenkinson, J., & McGill, G. (2013). Using 3D animation in biology education: Examining the effects of visual complexity in the representation of dynamic molecular events. *Journal Biochemistry, 39*(2), 42-49.

University of Education, Winneba http://ir.uew.edu.gh

Jibrin, A. G., & Nuru, R. A. (2007). *The role of ICT in teaching science, technology and mathematics education in Nigeria institutions.* A paper presented at the National Conference of Nigeria Primary and Teacher Education Association, at University of Jos. (July 31st – 3rd August).

Jiya, A. (2011). *Effects of teaching-with-analogy on academic performance and retention of evolution concepts among Nigeria Certificate in Education (NCE) biology Students*. Master's Thesis. Ahmadu Bello University, Zaria .Nigeria. Retrieved October 7, 2017, from http/www.ied.edu.hk/apfslt/v9_issue1/akpinar/index.htm

Johnson, D. W., & Johnson, R. T. (2008). *Introduction to Cooperative Learning. An overview of cooperative Learning*. Retrieved October 9, 2017, from *http/www. google.com*

Karen, B. S. (2008). Biology and society: A new way to teach tertiary science to non-science students. *Biology Education, 12*, 1-15.

Katırcıoğlu, H., & Kazancı, M. (2003). Effect of the use of computer in General Biology courses on academic achievement of student. *Hacettepe University, Journal of Education Faculty, 25*, 127-134.

Kauffman, G. B. (2003). Atomic orbitals on USEPR: The chemistry animation project. *Journal of College Science Teaching, 32*(6), 412-412.

Kearsley, G. (2000). *Online education: Learning and teaching in cyberspace*. Wadsworth.

University of Education, Winneba http://ir.uew.edu.gh

Kehoe, C., Stasko, J. T. I., & Taylor, A. (2001). Rethinking the evaluation of algorithm animations as learning aids: An observational study. *International Journal of Human-Computer Studies, 54*, 265-284.

Kelley, K., Clark, B., Brown, V., & Sitzia, J. (2003). Good practice in the conduct and reporting of survey research. *International Journal for Quality in Health Care*, *15*(3), 261-266.

Kerren, A. (2012). Visualizations and animations in learning systems. In N.M. Seel (Ed), *Encyclopedia of the science of learning,* (pp 3419-3421). Retrieved December 15, 2016, from www.springerlink.com

Khourey-Bowers, C. (2011). Active learning strategies: The top 10. *The Science Teacher, 78,* 38-42.

Kiili, K. (2005). Participatory multimedia learning: Engaging learning. *Australasian Journal of Education Technology, 21*(3), 1-12.

Kim, S., Yoon, M., Whang, S. M., Tversky, B., & Morrison, J. B. (2007). The effect of animation on comprehension and interest. *Journal of Computer Assisted Learning, 23*, 260-270. doi:10.1111/j.1365-2729.2006.00219.x

Kimball, S. M., White, B., Milanowski, A., & Borman, G. (2004). Examining the relationship between teacher evaluation and student assessment results in Washoe County. *Peabody journal of Education, 79*(4), 54-78.

University of Education, Winneba http://ir.uew.edu.gh

Kline, R. B. (2004). *Beyond significance testing: Reforming data analysis methods in behavioral research*, (p. 95). Washington DC: American Psychological Association.

Knowlton, D. S., & Morrison, G. R. (2002). *Principle for using animation in computer based instruction: Theoretical Heuristics for Effective.* Science Elected Com.

Kommers, P. A., Grabinger, S., & Dunlap, J. C. (1996). Hypermedia learning environm-ents: Instructional design and integration. New Jersey: Lawrence Erlbaum.

Kraidy, U. (2002). Digital media and education: Cognitive impact of information visualization. *J. Educ. Med. 27*, 95–106.

Kundu, C. L. & Tutoo, N. N. (2002). *Educational Psychology*. New Delhi: Sterling publishers.

Kuti, J. B. (2006*). Effect of multimedia instructional strategy on Senior Secondary Students' learning outcomes in Physics in Ogun State, Nigeria.* Unpublished M.Ed. thesis, University of Ibadan, Ibadan.

Kylie, S. (2012). History of animation. Retrieved November 27, 2017, from http://answers_history.org on

Lagoke, B. A. (2000). The efficiency of enriching biology teaching-with analogy on the performance of students of different achievement levels. *Journal of Science Education, 7*(1), 40-44.

University of Education, Winneba http://ir.uew.edu.gh

Lasseter, J. (2000). *Principles of traditional animation applied to 3D computer animation*. SIGGRAPH '87 Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques, pp. 35-44, New York: USA.

Lawal, T. E. (2007). “Think and Do” activity and its effect on the performance of pupils in primary science in selected primary schools in Zaria Municipality, Nigeria. *Journal of Science and Mathematics Education, University of Cape Coast, 3*(1), 87-92.

Lawson, A. E. (1993). The importance of analogy: A prelude to the special issue. *Journal of Research in Science Teaching, 30,* 1213–1214.

Leach, J., & Scott, P. (2003). Individual and sociocultural views of learning in science education. *Science and Education, 12,* 91-113.

Leedy, P. D., & Ormrod, J. E. (2005). *Practical research: Planning and design.* New Jersey: Pearson, Merrill Prentice Hall.

Lewalter, D. (2003). Cognitive strategies for learning from static and dynamic visuals. *Learning and Instruction*, *13*(2), 177-189.

Lewis, J., & Kattman, U. (2004). Traits, genes, particles, and information: Re-visiting students understanding of genetics. *International Journal of Science Education, 26*(2), 195-206.

Lih-Juan, C. L. (2000). Attributes of animation for learning scientific knowledge. *Journal of Instructional Psychology*, *27*(4), 228-238.

University of Education, Winneba http://ir.uew.edu.gh

Limon, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction, 11*, 357–380.

Lolita, J. (2015). Using analogies in teaching physics: A study on Latvian Teachers' views and experience. *Journal of Teacher Education for Sustainability, 17*(2), 53-73. doi: 10.1515/jtes-2015-0011

Lowe, R. K. (2003). Animation and learning: Selective processing of information in dynamic graphics. *Learning and Instruction*, *13*(2), 157-176.

Lowe, R. K. (2004). Animation and learning: Value for money. In R. Atkinson, C. McBeath, D. Jonas-Dwyer & R. Phillips (Eds.): *Beyond the comfort zone: Proceedings of the 21st ASCILITE Conference* (pp. 558-561). Perth.

Maduadum, M. A. (1994). Teachers' perception of difficult topics in the Nigerian senior secondary certificate biology. *Gobarau BI-Annual Multi-Discipline Journal of Education Katsina, 1*(1), 161-165.

Mangal, S. K. (2011). *Advanced Educational Psychology,* (pp. 257-270). New Delhi: PHI Learning Private Limited.

Marbach-Ad, G. (2001) Attempting to break the code in students comprehension of genetic concepts. *Journal of Biological Education, 35*(4), 183-189.

Marcelos, M., & Nagem, R. (2010). Comparative structural models of similarities and differences between vehicle and target in order to teach Darwinian evolution. *Science and Education, 19*, 599-623.

University of Education, Winneba http://ir.uew.edu.gh

Martin, J. (1993). Episodic memory: A neglected phenomena in the psychology of education. *Educational Psychologist. 28*(2)169-183.

Mayer, R. E. (2001). *Multimedia Learning*. Hillsdale, NY: Cambridge University Press.

Mayer, R. E. (2003). The promise of multimedia learning: using the same instructional design methods across different media. *Learning and Instruction, 13*(2), 125-139.

Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. *J. Educ. Psychol. 83*, 484–490.

Mayer, R. E., & Moreno, R. (2002). Animation as an aid to multimedia learning. *Educational Psychology Review, 14*(1), 87-99.

Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia learning in an interactive self-explaining environment: What works in the design of agent-based micro worlds? *Journal of Educational Psychology*, *95*(4), 806-813.

McClean, P., Johnson, C., Rogers, R., Daniels, L., Reber, J., Slator, B. M., & White, A. (2005). Molecular and cellular biology animations: Development and impact on student learning. *Cell Biology Education 4*(2), 169-79.

McKnight, A., Hoban, G., & Nielsen, W. (2011). Using slow motion for animated storytelling to represent non-Aboriginal pre service teachers' awareness of relatedness to country. *Australasian Journal of Educational Technology, 27*(1), 41-54.

University of Education, Winneba http://ir.uew.edu.gh

McLaughlin, J. S. (2001). Breaking out of the box: Teaching Biology with web based active learning modules. *The American Biology Teacher,* 63(2), 110-15.

Moreno, R., & Mayer, R. E. (2000a). A coherence effect in multimedia learning: The case for minimizing irrelevant sounds in the design of multimedia instructional messages. *J. Educ. Psychol. 92,* 117–125.

Mosenthal, P. B & Pailliotet, A. W. (Eds). (2000). *Reconceptualizing literacy in the age of media, multimedia and hypermedia,* NJ, USA: JAI/Ablex, Norwood

Musa, S., Ziatdinov, R., & Griffiths, C. (2013). Introduction to computer animation and its possible educational applications. In M. Gallová, J. Gunčaga, Z. Chanasová & M. M. Chovancová (Eds.), *New challenges in education. Retrospection of history of education to the future in the interdisciplinary dialogue among didactics of various school subjects* (pp. 177-205). Ružomberok, Slovakia: VERBUM

Nafees, M., Farouq, G., & Tahirkheli, S. A. (2012). Effects of Instructional strategies on academic achievements in a high school general science class. *International Journal of Business and Social Science, 3*(5), 161-166.

Nashon, S. (2004). The nature of analogical explanations: High school physics teachers use in Kenya. *Research in Science Education, 34*, 475-502.

Nawaf, A. H. S. (2016). Effectiveness of analogy instructional strategy on undergraduate student's acquisition of Organic Chemistry concepts in Mutah University. *Jordan Journal of Education and Practice, 7*(8), 70-74.

University of Education, Winneba http://ir.uew.edu.gh

Neghad, S. L. & Shahraray, M. (2001). Relationship of locus of control and self- regulation with academic achievement. *Journal of Psychology and Educational Sciences*, 2, 175-198.

Newby, T. J., Ertmer, P. A., & Stepich, D. A. (1995). Instructional analogies and the learning of concepts. *ETR&D, 43*(1), 5-18.

Nichols, K., Ranasinghe, M. & Hanan, J. (2012). Translating between representations in a social context: A study of undergraduate science students' representational fluency. *Instructional Science*, *13*, 6-13.

Nielsen, J. (1995). *Guidelines for multimedia on the web*. Retrieved December 19, 2017 from http://www.useit.com/alertbox/9512.html

Njoku, Z. C. (2004). Effectiveness of model for science and technology instruction. *Journal of Science Teachers Association of Nigeria 39*, 45-51.

Novak, J. D., & Canas, A. J. (2008). *The theory underlying concept maps and how to construct and use them.* Retrieved August 9, 2017 from http://cmap.ihmc.us

Nwagbo, C. R. (1999). Effects of guided-discovery and expository teaching methods on the attitude towards biology of students of different levels of scientific literacy. *Journal of Science Teacher's Association of Nigeria*, *34*(1 & 2), 66-73.

Nwagbo, C. R., & Okoro, A. U. (2012). Effects of interaction patterns on achievement in biology among secondary school students. *Journal of Science Teachers Association of Nigeria*. *47*(1), 22-32.

University of Education, Winneba http://ir.uew.edu.gh

Nwankwo, M. C., & Madu, B. C. (2014). Effect of analogy teaching approach on students' conceptual change in physics. *Greener Journal of Educational Research, 4*(4), 119-125. DOI: http://dx.doi.org/10.15580/GJER.2014.4.03241416

Nworgu, B. G. (2006). *Educational Research. Basic Issues and Methodology.* (2nd ed).84-91. University Trust Publishers.

Nwosu, A. A. (1998). Teachers' understanding of biology curriculum content and required practices. *Journal of the Science Teachers Association of Nigeria , 33*(1 & 2), 78-83.

Nzelum, V. N. (2010). *STEM Journal of Anambra State (STEMJAS).* Amaka Dreams Ltd. Awka.

Obomanu, B. J., Nwanekezi, A. U., & Ekineh, D. R. (2014). Relative effects of two forms of pedagogy on secondary school students' performance in ecology concepts. *International Journal of Education and Research, 2*(10), 237-250.

Ogbu, J. E. (2010). Effects of classroom interaction pattern on students' interest in basic electricity. *Journal of the Nigerian Academy of Education Development, 6*(1), 19-29.

Ogundokun M. O., & Adeyemo D. A. (2010). Emotional intelligence and academic achievement: The moderating influence of age, intrinsic and extrinsic motivation. *The African Symposium, 10* (2), 127-141.

University of Education, Winneba http://ir.uew.edu.gh

Ogunkunle, A. R., & Gbamanja, T. S. P. (2006). Constructivism: An instructional strategy for sustaining student's self-concept in secondary school Mathematics. *Journal of the Science Teachers Association of Nigeria 41*(1 & 2), 31-36.

Okebukola, P. A. (2005). *The race against obsolescence: Enhancing the relevance of STAN to national development.* Memorial Lecture of STAN. Taste & Styles Co. Abuja.

Okebukola, P. A., & Jegede, O. J. (1995). Students' anxiety towards and perception of difficulty of some biology concepts under the concept mapping heuristic. *Research Science Technology Education, 7*(1), 85-91.

Okeke O. J. (2011). *Effect of mindmapping teaching strategy on students' achievement, interest and retention in senior secondary school chemistry.* Ph.D. Thesis, University of Nigeria, Nsukka. Retrieved August 1, 2017, from http://www.unn.edu.ng/publications/files/images/Okeke,%20O.pdf

Okoli, J. N. (2006). Effect of investigative laboratory approach and expository method on acquisition, different levels of scientific literacy. *Journal of the Science Teachers Association of Nigeria, 4*(1 & 2), 79-88.

Okoye, A. C. (2003). *Effect of audio taped instructions supported with pictures on students' achievement and retention in selected Biology content*. Unpublished M.Ed. Thesis, University of Nigeria, Nsukka.

Oosterhof, A. (1990). *Classroom application of educational measurements.* Columbus, OH: Merrill.

University of Education, Winneba http://ir.uew.edu.gh

Opara, J. A. (2011). Inquiry method and student academic achievement in biology: Lessons and policy implications. *American-Eurasian Journal of Scientific Research, 6*(1), 28-31.

Orgil, M., & Bodner, G. (2004). What research tells us about using analogies to teach chemistry. *Chemistry Education: Research and Practice, 5*(1), 15-32.

Orgil, M. K., & Thomas, M. (2007). Analogies and the 5E model. *Science Teacher, 74*(1), 40-45.

Owolabi, T. (2007). *The use of analogy as vehicle for achieving effective physics delivery in some selected senior secondary schools in Lagos*. Proceeding of Science Teachers Association of Nigeria National Conference.

Owolabi O. T., & Oginni O. I. (2014). Effectiveness of animation and multimedia teaching on students' performance in science subjects. *British Journal of Education, Society & Behavioural Science. 4*(2), 201-210.

Oyedokun, M. R. (2002). Identification of difficult topics in the senior secondary school certificate biology syllabus as perceived by students. *The Nigerian Teacher Today, 10*(1), 110-120.

Ozdemir, D. (2009). *The effects of context-dependency of seductive details on recall and transfer in a multimedia learning environment*. Unpublished Doctoral Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Paas, F., Renkl, A., & Sweller, J. (2003) Cognitive load theory and instructional design: Recent developments. *Educational Psychologist 38*, 1–4.

University of Education, Winneba http://ir.uew.edu.gh

Paivio, A. (1986). *Mental representations: A dual coding approach*. Oxford, England: Oxford University Press.

Paivio, A. (1990). Dual coding theory: retrospect and current status. *Can J Psychol. 45*, 255–287

Paizi, M., Shahraray, M., Farzad, V., Ullah, R., & Safai, P. (2007). Effectiveness of assertiveness training on the happiness and academic achievement students. *Journal of Psychology Studies*, *4*, 43-25.

Palima, D. & Ines, M. (2004). *Physics*. Quezon City: Phoenix Publishing House.

Paris, N., & Glynn, S. M. (2004). Elaborate analogies in science text: Tools for enhancing pre service teachers' knowledge and attitudes. *Contemporary Educational Psychology, 29*, 230-247.

Piaget, J. (1980). *Experiments in Contradiction*. Chicago: University of Chicago Press.

Pittman, K. M. (1999). Student generated analogies: Another way of knowing. *Journal of Research in Science Teaching, 36*(1), 1-22.

Podolefsky, N., & Finkelstein, N. (2007). Analogical scaffolding and the learning of abstract ideas in physics: An example from electromagnetic waves. *Physical Review Special Topics-Physics Education Research, 3*(1), 101-109

Polk, A. R., (2013). The effect of teaching biology concepts with animations compared to static cartoons on content retention. Master's Thesis, Louisiana State University. Retrieved December 5, 2017 from http://www.unn.edu.ng

University of Education, Winneba http://ir.uew.edu.gh

Powell, J. V., Aeby, V. G., & Carpenter, T. (2003). A comparison of student out comes with and without teacher facilitated computer-based instruction. *Computers Education, 40*, 183-191.

Pruneski, J., & Donovan S. (2016). *The use of animations in undergraduate biology education: Going beyond the content*. Dept. of Biological Sciences, University of Pittsburgh, Pittsburgh, PA 15260.

Rashmil, L., & Bina P. (2013). Effect of achievement motivation on high and low achievers of secondary school students: A comparative study. *International Journal of Basic and Advanced Research, 2*(6), 133-135.

Richland, L. E. & Simms, N. (2015). Analogy, higher order thinking and education. *Wiley Interdisciplinary Reviews: Cognitive Science, 6*(2), 177-192

Rieber, L. P. (1990). Animation in computer-based instruction. *Educ. Technol. Res. Dev. 38*, 77-86.

Rieber, L. P. (1994). Using computer animated graphics in science Instruction with children. *Journal of Educational Psychology*, *82*(1), 135-140.

Rieber, L. P., Tzeng, S. C., & Tribble, K. (2004). Discovery learning, representation, and explanation within a computer-based simulation: Finding the right mix. *Learning and Instruction*, *14*(3), 307-323.

Rogers, M. (2007). An inquiry-based course using physics in cartoons and movies. *The Physics Teacher, 45*(1), 38-41.

University of Education, Winneba http://ir.uew.edu.gh

Rotbain, Y., Marbach-Ad, G., & Stavy, R. (2008). Using computer animation and illustration activities to improve high school students' achievement in molecular genetics. *Journal of Research in Science Teaching, 45*(3), 273-292.

Rowe, G. W., & Gregor, P. (1999). A Computer based learning system for teaching computing, implementation and evaluation. *Computers Education*, *33*, 65-76.

Rozenblit L., & Keil F. (2002). The misunderstood limits of folk science: An illusion of explanatory depth. *Cognitive Science, 26*, 521–562. Retrieved August 20, 2017 from http://onlinelibrary.wiley.com/doi/10.1207/s15516709cog2605_1/epdf

Russell, J., Kozma, R., Zohdy, M., Susskind, T., Becker, D., & Russell, C. (2000). *Simultaneous Multiple Representations in Chemistry*. New York: John Wiley.

Saka, A., & Akdeniz, A. R. (2006). Development of computer assisted material about genetics and its practise according to 5E model. *The Turkish Online Journal of Education Technology*, *5*(1), 14-22.

Salau, M. O. (2002). The effect of class size on achievement of different ability groups in mathematics. *Journal Science Teachers 'Association of Nigeria, 31*(1), 27-33.

Salih, M. (2010). Developing thinking skills in Malaysian science students via an analogical task. *Journal of Science and Mathematics Education in Southeast Asia, 33,* 110-128.

University of Education, Winneba http://ir.uew.edu.gh

Sancar, M. J., & Greenbowe, T. J. (2000). Addressing student misconceptions concerning electron flow in aqueous solutions with instructions including computer animations and conceptual change strategies. *International Journal of Science Education, 22*(5), 521-537.

Sangin, M., Molinari, G., Dillenbourg, P., Rebetez, C., & Betrancourt, M. (2006). *Collaborative learning with animated pictures: The role of verbalizations, Proceedings of the Seventh International Conference of the Learning Sciences.* Bloomington, USA.

Sani, H. M. (2006). Effect of analogy on conceptual understanding of chemical equilibrium among secondary school students in Minna Municipal, Niger State. Minna *Journal of Science Education and Allied Research*. *2*(1), 46-51.

Santos, R. S. (2009). *Impact of flash animation on learning concept of matter among elementary students*. Master's Thesis, University of Texas-Pan American.

Sarantopoulos, P., & Tsaparlis, G. (2004). Analogies in chemistry teaching as a means of attainment of cognitive and affective objectives: A longitudinal study in a naturalistic setting, using analogies with a strong social content. *Chemistry Education Research and Practice, 5*(1), 33-50.

Savinainen, A., Scott, P., & Viiri, J. (2005). Empirical study on the efficiency of bridging analogies in learning science. *Science Education, 89, 175-195.*

University of Education, Winneba http://ir.uew.edu.gh

Scheiter, K., Gerjets, P., & Catrambone, R. (2006). Making the abstract concrete: Visualizing mathematical solution procedures. *Computers in Human Behavior, 22*(1), 9-25.

Schnotz, W. (2001). *Educational promises of multimedia learning from a cognitive perspective, Multimedia Learning: Cognitive and Instructional Issues,* **(**pp. 9-29**)**. Amsterdam: Elsevier.

Schonborn, K. J., & Anderson, T. R. (2006). The importance of visual literacy in the education of Biochemists. *Biochemistry and Molecular Biology Education, 34* (2), 94-102

Seel, N. (Ed.) (2012). *Encyclopedia of the sciences of learning,* (pp. 3419–3421). NY, US: Springer.

Şekercioğlu, A. & Kocakülah, M. (2008). Grade 10 students' misconceptions about impulse and momentum. *Journal of Turkish Science Education, 5*(2), 47-59.

Simon, M. K. (2011). *Dissertation and scholarly research: Recipes for success*. Seattle, WA: Dissertation Success, LLC.

Spezzini, S. (2010). Effects of visual analogies on learner outcomes: Bridging from the known to the unknown. *International Journal for the Scholarship of Teaching and Learning, 4*(2) 1-35. Retrieved December 22, 2017 from https://digitalcommons. georgiasouthern.edu/cgi/viewcontent.cgi?article=1231&context=ij-sotl

University of Education, Winneba http://ir.uew.edu.gh

Sriram, K., Ganesh, L. S., & Madhumathi, R. (2013). Inferring principles for sustainable development of business through analogies from ecological systems. *IIMB Management Review, 25*(4). DOI:10.1016/j.iimb.2012.12.005.

Steinberg, E. R. (1991). *Teaching computers to teach*. Hillsdale, NY: Prentice Hall.

Stith, B. J. (2004). Use of animation in teaching cell biology. *Cell Biology Education 3*(3), 181-88.

Sullivan, G. M., & Feinn, R. (2012). Using effect size: Why the P value is not enough. *Journal of Graduate Medical Education, 4*(3), 279–282. doi:10.4300/JGME-D-12-00156.1

Suleiman, A. M. (2011). *Effects of inquiry teaching method on academic achievement, retention and attitudes towards chemistry among diploma students of Kano State Polytechnic.* Unpublished M.Ed Thesis, Ahmadu Bello University, Zaria.

Sweller, J. (1999). *Instructional Designs in Technical Areas*. Melbourne, Australia: ACER Press.

Sweller, J., van Merrienboer, G. J., & Paas, F. (1998). Cognitive Architecture and Instructional Design. *Educational Psychology Review, 10*(3), 251-296.

Taber, H. K., Martens, R. L., & van Merriënboer, J. G. (2004). Multimedia instructions and cognitive load theory: Effects of modality and cueing. *British Journal of Educational Psychology, 74*, 71-81.

University of Education, Winneba http://ir.uew.edu.gh

Tayo, D. (2012). Effects of Animated Agricultural Package on Attitude and Performance of JSS students in South Western Area, Nigeria. *MJSS Journal 5,* 44-55.

Teijlingen, E., & Hundley, V. (2011). *The importance of pilot studies*. Social research update. United Kingdom: Guildford GU2 5XH, Department of Sociology, University of Surrey.

Tekdal, M. (2002). *Development of interactive physics simulations and its active use.* National Science and Mathematics Education Congress, Ankara.

Templin, M. A., & Fetters, M. K. (2002). A working model of protein synthesis using Lego™ building blocks. *American Biology Teacher, 64*(9), 673-678.

Thiele, R. B., Venville, G. J., & Treagust, D. F. (1995). A comparative analysis of analogies in secondary biology and chemistry textbooks in Australian schools. *Research in Science Education, 25*, 221-230.

Thomas, O. O., & Israel, O. O. (2014). Effectiveness of animation and multimedia teaching on students' performance is science subjects. *British Journal of Education, Society and Behavioral Science, 4*(2), 1-15.

Tibell, L. A., & Rundgren, C. J. (2010). Educational challenges of molecular life science: Characteristics and implication for education and research. *Life Science Education, 9,* 25-33.

University of Education, Winneba http://ir.uew.edu.gh

Trevisan, M. S., Oki, A. C. & Senger, P. L. (2009). An exploratory study of the effects of time compressed animated delivery multimedia technology on student. *Journal of Science Education and Technology, 19*(3), 293–302.

Tuckman, B. W. (1975). *Measuring educational outcomes.* Harcourt Brace Hovawick Inc. NewYork.

Ugwumba, A. O., & Bitrus, Z. W. (2014). Effects of analogy instructional strategy, cognitive style and gender on senior secondary school students' achievement in some Physics concepts in Mubi Metropolis, Nigeria. *American Journal of Educational Research*, *2*(9)788-792. doi: 10.12691/education-2-9-13.

Ukpebor, J. N., & Ozobokeme, J. K. (2007). The influence of gender and students' self-concept on their mathematics achievement. *Multidisciplinary journal of Research Development, 9*(1), 100-107.

Usman, I. A. (2000). *The Relationship between students' performance in practical activities and their academic achievement in integrated science using NISTEP mode of teaching.* Unpublished Doctorate of Philosophy Dissertation, Ahmadu Bello University, Zaria.

Usman, I. A. (2010). The Effects of indoor and outdoor instructional methods on academic achievement of J.S.S integrated science students in Zaria local government area, Kaduna State. *Journal of Science and Mathematics Education, 1*(1), 66-73.

University of Education, Winneba http://ir.uew.edu.gh

Uzma, S. (2016). Effectiveness of animation-based and analogy-based instructions on tenth-grade students' achievement in Chemistry: A comparative study. *European Academic Research 3*(11), 12556-12579.

Venville, G. J., & Treagust, D. F. (1997). Analogies in biology education: A contentious issue. *The American Biology Teacher, 59,* 282–287.

Venville, G. J., & Donovan, J. (2008). How pupils use a model for abstract concepts in genetics. *Journal of Biological Education, 43*(1), 6-14. doi:10.1080/00219266.2

008.9656143

Vonganusith, V. & Pagram, J. (2008). *Web-based courses to support EFL learning for pre-service teachers: A Thai pilot study*. Edith Cowan University, Research Online, 559-570.

Vosniadou, S. (1989). Analogical reasoning and knowledge acquisition: A developmental perspective. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning*, (pp. 1–15). New York: Cambridge University Press.

Vratulis, V., Clarke, T., Hoban, G., & Erickson, G. (2011). Additive and disruptive pedagogies: The use of slow motion as an example of digital technology implementation. *Teaching and Teacher Education, 27,* 1179-1188.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological process.* Cambridge, MA: Harvard University Press.

University of Education, Winneba http://ir.uew.edu.gh

Weiss, R. E., Knowlton, D. S., & Morrison, G. R. (2002). Principles for using animation in computer based instruction: Theoretical heuristics for effective design. *Computers in Human Behavior, 18*, 465-477. doi:10.1016/S07475632(01)000498

Weng, X. (2003). Integration of modern and traditional teaching strategies in plant physiology. *The China Papers*, pp. 53-57

West African Examination Council (2013). *Chief Examiners' Report.* WAEC Press Ltd.

West African Examination Council (2014). *Chief Examiners' Report.* WAEC Press Ltd.

West African Examination Council (2015). *Chief Examiners' Report*. WAEC Press Ltd.

West African Examination Council (2016). *Chief Examiners' Report.* WAEC Press Ltd.

West African Examination Council (2017). *Chief Examiners' Report*. WAEC Press Ltd.

Wilbers, J. & Duit, R. (2006). Post-festum and heuristic analogies. In P. J. Aubusson, A. G. Harrison, S. M. Ritchie (Eds.), *Metaphor and Analogy in Science Education*, Netherlands: Springer, pp. 37-49.

Wittrock, M. C., & Alesandrini, K. (1990). Generation of summaries and analogies and analytic and holistic abilities. *American Educational Research Journal*, *27*(3), 489-502. DOI: 10.3102/00028312027003489

Yager, R. E. (1995). Constructivism and the learning of science. In S.M. Glynn & R. Duit (Eds). *Learning science in the schools: Research reforming practice* (pp. 35-38). Mahwah, NJ: Erlbaum.

University of Education, Winneba http://ir.uew.edu.gh

Yanowitz, K. L. (2001). The effects of analogies on elementary school students' learning of scientific concepts. *School Science and Mathematics, 101*, 133-142.

Yerrick, R. K., Doster, E., Nugent, J. S., Parke, H. M., & Crawley, F. E. (2003). Social interaction and the use of analogy: An analysis of pre service teachers' talk during physics inquiry lessons. *Journal of Research in Science Teaching, 40*(5), 443-463.

Yilmaz, S., & Eryilmaz, A. (2010). Integrating gender and group differences into bridging strategy. *Journal of Science Education and Technology, 19*, 341-355.

Yusuf, M. O. & Afolabi, A. O. (2010). Effects of computer assisted instruction on secondary school students' performance in Biology. *The Turkish Online Journal of Educational Technology, 9*(1).

Zhu, L., & Grabowski, B. L. (2005). Web-based animation or static graphics: Is the extra cost of animation worth it? *Journal of Education Multimedia and Hypermedia, 15*(3), 329-347.

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APPENDIX A

Tano North Municipal Education Chief Examiner's Annual Reports on May/June WASSCE Result in Biology from 2014 to 2017

	SCHOOLS/ YEAR															
	BOAKYE TROMO SHTS				**SERWAA KESSE SHS**				**YAMFO SHS**				**BOMAA SHS**			
GRADE	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017
A1	0	0	2	0	8	3	10	4	0	0	1	0	1	1	3	2
B2	2	2	3	2	9	7	15	6	2	2	2	4	4	3	6	4
B3	3	5	4	4	11	13	20	14	3	4	5	3	6	6	5	4
C4	4	2	10	8	17	15	10	17	9	5	7	7	14	16	17	10
C5	4	4	6	7	10	10	19	16	8	5	9	7	7	10	8	7
C6	9	10	10	11	18	15	10	17	11	12	10	10	14	16	17	12
D7	21	20	23	21	10	12	10	17	20	24	18	19	8	14	10	19
E8	13	9	12	15	8	11	11	15	14	25	15	16	7	9	4	10
F9	22	23	15	15	11	14	6	11	21	21	15	16	12	11	7	12
Absent(%)	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0
TOTAL	**78**	**75**	**85**	**84**	**103**	**100**	**111**	**118**	**88**	**74**	**83**	**82**	**73**	**86**	**77**	**79**
% Passed:																
A1-C6 (%)	28	31	41	38	71	63	75	62	38	38	40	38	63	43	60	49
D7-E8 (%)	44	39	41	44	17	22	20	28	38	34	46	43	31	44	32	36
% Failed:																
F9 (%)	28	30	18	18	11	14	5	9	24	28	13	19	16	13	8	15

Field Source (2017)

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APPENDIX B

DNA Concepts Achievement Test (DNACAT) for Second Year Biology Students in the Tano North Municipal SHS

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF SCIENCE EDUCATION

Dear Student,

This test is intended to measure your understanding, performance and retention of second on the topic "DNA structure and replication, transcription and translation concepts" in biology. This is not part of your continuous assessment and result of this test will be treated confidentially. Your responses will be helpful in teaching and learning of DNA molecular concepts among Senior High School biology students. The test consists of three (3) sections; Sections A, B and C.

Thank you.

Bio Data: Fill and mark (√) where applicable in the box provided

Name of student……………………………………………….

Class: Home Economics ( ) Science ( )

Group: One ( ) Two ( )

Sex: Male ( ) Female ( )

Age………………………..

TIME: 40 minutes

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SECTION A (Multiple Choice Objective Test)

Instruction: This section consists of twenty (20) multiple choice items with each question followed by four options lettered "A to D". Choose the most appropriate option for your answer by circling around the letter that corresponds to the chosen option with a pencil. If you decide to change your answer, erase the first one completely and re-circle your new choice.

1. How does termination of translation take place?

   A. The 5' cap is reached

   B. The end of the mRNA molecule is reached

   C. A stop codon is reached

   D. The poly-A tail is reached

2. A particular triplet of bases in the template strand of DNA is 5' AGT 3'. The corresponding codon for the mRNA transcribed is

   A. 3' UGA 5'

   B. 5' TCA 3'

   C) 3' ACU 5'

   D) 3' UCA 5'

3. What is the chemical composition of DNA?

   A. protein

   B. nucleotides

   C. genes

   D. traits

4. After DNA replication of a DNA double helix molecule, two DNA double helices result. Which of the following statements best describes the composition of the two remaining double helices?

   A. Both strands in one of the two helices are new and both strand of other helix are old

   B. In each of the two helices, one of the two strands is new

   C. Random pieces along each strand of both helices are newly synthesized

   D. None of the above

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5. A new DNA strand elongates only in the 5’ to 3’ direction because

A. replication must progress toward the replication fork

B. DNA polymerase begins adding nucleotides at the 5’ end of the template

C. DNA polymerase can add nucleotides only to the free 3’ end

D. the polarity of the DNA molecule prevents addition of nucleotides at the 3’ end

6. What chemical units make up a nucleotide?

A. thymine, guanine, uracil, phosphates

B. phosphates, nitrogen bonds, bases

C. 5-carbon sugar, phosphates, nitrogen bases

D. ribose, phosphates, bases

7. During DNA replication, what serves as the template for synthesis of a new strand?

A. one of the two strands of the double helix

B. random pieces of both strands of the double helix

C. each of the two strands of the double helix

D. one strand of DNA and one strand of RNA

8. What is the term for a three-nucleotide sequence that codes for an amino acid?

A. base C. amine

B. codon D. serine

9. What are the similarities between DNA and RNA molecules?

A. Both consist of a double helix.

B. Both contain the same sugar.

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C. Both contain the four nitrogen bases: Adenine, Thymine, Guanine and Cytosine.

D. Both contain nucleotides, which include sugar and a phosphate group

10. In the double helix, the _____ and the ____ form the rail of the "ladder" and the ____ form the rungs of the "ladder".

A. deoxyribose, phosphates, nitrogen bases

B. phosphates, nitrogen bases, deoxyribose

C. nitrogen bases, deoxyribose, phosphates

D. guanine, cytosine, uracil

11. The central dogma of molecular biology states that information flows in one direction from

A. nucleic to RNA to cytoplasm

B. ribosomes to protein

C. genes to nucleic to ribosomes

D. DNA to RNA to proteins

12. The process of making new DNA molecules is semiconservative. This means that every new DNA molecules is composed of

A. two completely identical strands of DNA

B. one original and one new strand of DNA

C. one strand of DNA and one strand of RNA

D. two strands that mix original and new DNA

13. Which of the following DNA sequences is complementary to the base sequence ACCGTAT?

A. GTTACGC

B. UCCGTAT

C. TGGCATA

D. CAATGCG

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14. What components are common to all the nucleotides in the RNA molecule?

A. Phosphate group, amino acid and deoxyribose.

B. Phosphate group, nitrogen base and deoxyribose.

C. Phosphate group, amino acid and ribose.

D. Phosphate group, nitrogen base and ribose

15. Which of the following events occurs directly after a DNA molecule is unzipped?

A. Mismatched nucleotide bases are identified and replaced

B. Free-floating nucleotides pair up with exposed bases

C. Identical double-stranded DNA molecules are formed

D. Enzymes break hydrogen bonds between base pairs

16. During translation, amino acids bond with the anticodon to form

A.codons C. genes

B.nucleotides D.proteins

17. Which phrase best describes translation?

A. converts mRNA into a protein

B. catalyzes bonds between amino acids

C. produces RNA from DNA molecules

D. recycles tRNA molecules for reuse

18. Because of base pairing in DNA, the percentage of

A. adenine molecules in DNA is about equal to the percentage of guanine molecules

B. pyrimidines in DNA is about equal to the percentage of purines

C. purines in DNA is much greater than the percentage of pyrimidines

D. cytosine molecules in DNA is much greater than the percentage of guanine

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19. All of the following are true about DNA replication in prokaryotic cells except

A. replication begins at many sites along the DNA

B. replication begins at one site along the DNA loop

C. replication occurs in two opposite directions

D. there are two replication forks

20. The structure of the DNA molecule may be changed through

A. evolution B. heredity

C. variation D. mutation

SECTION B (True or False Test Items)

Instruction: Read each statement carefully and indicate whether it is true or false by underlying your choice of the two options given.

21. Codons are part of the molecular structure of mRNA. True/False

22. During the process of transcription, DNA serves as the template for making ribosome which leaves the nucleus with the message from DNA. True/False

23. Adenine and guanine are the two pyrimidines found in DNA. True/False

24. Proteins are made in the cytoplasm whereas DNA is found only in the mitochondria. True/False

25. Transfer RNA carries a nucleotide to its correct codons. True/False

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SECTION C (Fill-in the Blank)

Instruction: In the blank space provided in each of the given sentences, write the most befitting word(s) that will make the resulting sentences valid.

26. The process of converting RNA code into an amino acid sequence is called…………

27. Amino acids join together with……………………… bonds

28. In the formation of an mRNA molecule, thymine is replaced by…………………..

29. A promoter is a binding site for ……………………………...

30. The enzymes responsible for adding nucleotides to the exposed DNA bases during replication are…………………………........

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APPENDIX C

Marking Scheme for DNA Concepts Achievement Test (DNACAT) [30 marks]

1. C
2. D
3. B
4. B
5. C
6. C
7. C
8. B
9. D
10. A
11. D
12. B
13. C
14. D
15. B
16. D
17. A
18. B
19. A
20. D
21. True
22. False
23. False
24. False
25. False
26. Translation
27. Peptide
28. Uracil
29. DNA polymerase
30. DNA polymerase

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APPENDIX D

DNACAT Discrimination and Difficulty Indices obtained from the Pilot Test

Question No.	$DI = \frac{RU - RL}{\frac{1}{2}N}$	$D_f = \frac{R}{T}$
1	0.58	0.62
2	0.67	0.44
3	0.48	0.53
4	0.66	0.43
5	0.57	0.53
6	0.53	0.49
7	0.62	0.18*
8	0.47	0.61
9	0.60	0.41
10	0.58	0.59
11	0.75	0.49
12	0.51	0.66
13	0.70	0.54
14	0.69	0.42
15	0.73	0.40
16	0.58	0.62
17	0.71	0.44
18	0.56	0.46
19	0.64	0.20*
20	0.52	0.44

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21	0.76	0.59
22	0.72	0.61
23	0.77	0.46
24	0.68	0.53
25	0.73	0.60
26	0.69	0.47
27	0.59	0.43
28	0.66	0.55
29	0.61	0.47
30	0.74	0.58

DI = Discrimination Index

Df = Difficulty Index

* = Items/questions which were reconstructed

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APPENDIX E

DNACAT Computation of KR-20 Reliability Coefficient obtained from the Pilot Test

Items No.	No. passing	No. failing	Proportion passing (p)	Proportion failing (q)	pq
1	27	13	0.68	0.33	0.2244
2	19	21	0.48	0.53	0.2544
3	25	15	0.63	0.38	0.2394
4	19	21	0.48	0.53	0.2544
5	23	17	0.58	0.43	0.2494
6	24	16	0.60	0.4	0.2400
7	22	18	0.60	0.45	0.2700
8	19	21	0.48	0.53	0.2544
9	25	15	0.63	0.38	0.2394
10	19	21	0.48	0.53	0.2544
11	23	17	0.58	0.43	0.2494
12	27	13	0.68	0.33	0.2244
13	22	18	0.60	0.45	0.2700
14	19	21	0.48	0.53	0.2544
15	25	15	0.63	0.38	0.2394
16	19	21	0.48	0.53	0.2544
17	23	17	0.58	0.43	0.2494
18	27	13	0.68	0.33	0.2244
19	22	18	0.60	0.45	0.2700
20	19	21	0.48	0.53	0.2544
21	25	15	0.63	0.38	0.2394
22	19	21	0.48	0.53	0.2544
23	23	17	0.58	0.43	0.2494
24	27	13	0.68	0.33	0.2244
25	22	18	0.6	0.45	0.2700
26	19	21	0.48	0.53	0.2544
27	25	15	0.63	0.38	0.2394
28	19	21	0.48	0.53	0.2544
29	23	17	0.58	0.43	0.2494
30	27	13	0.68	0.33	0.2244
Total					**7.43**

$$\text{KR-20} = \frac{k}{k-1}\left(1 - \frac{\sum pq}{s^2}\right)$$

Where:

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KR-20 is the Kuder-Richardson formula 20

k is the total number of test items

Σ indicates to sum

p is the proportion of the test takers who pass the test item

q is the proportion of test takers who fail the test item

s^2 is the variance of the total test scores (The variation of the total exam scores)

Mean = $\frac{\sum X}{N} = \frac{677}{40}$ = 16.925

$S^2 = \frac{\sum X^2 - (\sum X)^2/N}{N} = \frac{13437 - (677)^2/40}{40}$

$= \frac{1978.775}{40} = 49.4693$

$$\text{KR-20} = \frac{30}{30-1}\left(1 - \frac{7.43}{49.4693}\right) = \frac{30}{29}\left(1 - \frac{7.43}{49.4693}\right)$$

= 1.034482759 x (1 – 0.15019416)

KR-20 = 1.034482759 x 0.84988584

KR-20 = 0.87910949

KR-20 = 0.88

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APPENDIX F

Examples of Some Analogies Used to Teach Students in the Analogy-based Instructional Group: Building a House and Bread Baking Analogies (Enriched Multiple Analogy) for DNA Concepts

LIKE (WHERE THE ANALOGIES MATCHES THE CONCEPTS)		
Transcription and Translation Concepts	**Building a House Analogy**	**Bread Baking Analogy**
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 (tRNA)	Blocks and other materials are sent to the supervisor by truck	Ingredients are sent to chef by kitchen hands or car
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

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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

LIMITATIONS/UNLIKE (WHERE THE ANALOGIES BREAKS DOWN)

- Protein synthesis are sub microscopic whereas building a house and baking bread are not
- Blocks and ingredients for making bread can be cut up whereas amino acids are always used in their entirely
- 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
- Proteins are naturally made by the body cells whereas bread baking/building a house is made/build by man

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APPENDIX G

Some Snapshots in the Animations Used to Teach Students in the Animation-based Instructional Group in DNA Concepts