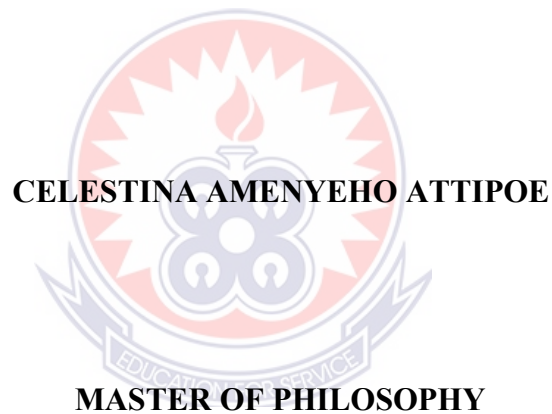


UNIVERSITY OF EDUCATION, WINNEBA

Using computer based animations in the teaching and learning of control and coordination to form two biology students in Zion College, Anloga



UNIVERSITY OF EDUCATION, WINNEBA

**USING COMPUTER BASED ANIMATIONS IN THE TEACHING AND
LEARNING OF CONTROL AND COORDINATION TO FORM TWO
BIOLOGY STUDENTS IN ZION COLLEGE, ANLOGA**



**A thesis in the Department of Biology Education,
Education Faculty of Science Education, submitted to the
School of Graduate Studies in partial fulfilment
of the requirements for the award of the degree of
Master of Philosophy
(Biology Education)
in the University of Education, Winneba**

MAY, 2024

DECLARATION

STUDENT'S DECLARATION

I, CELESTINA AMENYEHO ATTIPOE, 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 that 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

SIGNATURE:

DATE:

DEDICATION

I am dedicating this thesis to my beloved husband, Dziewornu Tamakloe and son, Nutifafa Tamakloe.



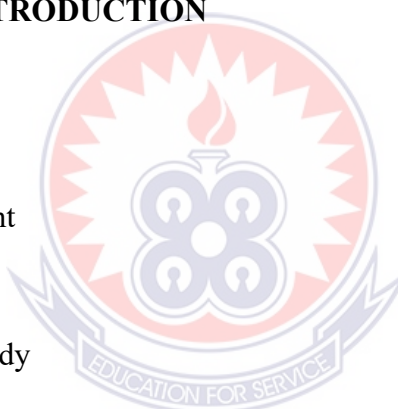
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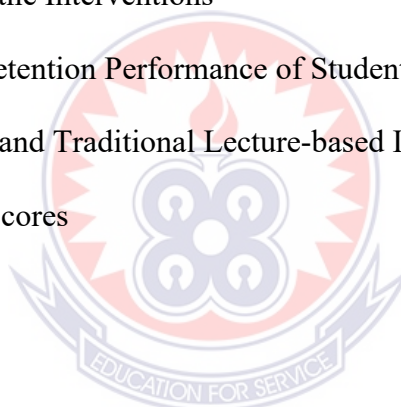


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GLOSSARY

[Operational Definition of Terms and Abbreviations]

CBA: Computer Based Animation; computer-generated motion imagery which is used to depict ideas.

ICT: Information and Communication Technology, basically the use of technology to store, retrieve, transmit and manipulate information.

STEM: Science, Technology, Engineering and Mathematics, involving a group of academic disciplines that involve the study and application of scientific principles, mathematics concepts and engineering techniques.

WAEC: The West Africa Examination Council

WASSCE: West Africa Secondary School Certificate Examination

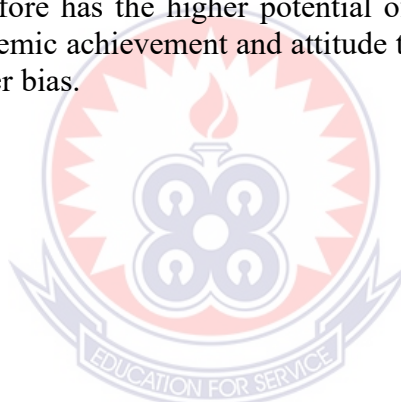
UNESCO: The United Nations Educational, Scientific and Cultural Organization is a specialized agency of the United Nations with the aim of promoting world peace and security through international cooperation in education, arts, sciences and culture.

JICA: Japan International Cooperation Agency to support Ghana in its effort, JICA's cooperation is primarily focused on 1) Quality Infrastructure for Economic Growth; 2) Industrial and Agricultural Development; 3) Universal Health Coverage; and 4) Capacity

AIT: Accra Institute of Technology, Ghana in Collaborations with Ministry of Education, undertook a brilliant project to equip teachers with ICT skills that will inform them, equip them to integrate it tools and software in the teaching and learning process.

ABSTRACT

The purpose of the study was to see how successful computer-based animation may be in teaching and learning of Coordination and Control concepts in Biology at Zion College in the Anloga District of the Volta Region of Ghana. In all, a total of 117 elective Biology students were sampled for this study, and they were split into two groups (experimental group and control group). The experimental group was taught coordination and control through a computer-based animation method, while the control group was taught same coordination and control through a traditional lecture-based method. Control and coordination Achievement Test (CCAT) with a reliability coefficient of 0.91 was used to measure students' achievement and retention before and after treatments, while Students Attitude Questionnaire on Coordination and Control (SAQCC) was used to examine the students' attitude toward the concepts of coordination and control. Data was analysed using various statistical tool including mean, standard deviation, paired sampled *t*-test, independent sampled *t*-test and Cohen *d* effect size at a significant level of 0.05. The study brought to light that the use of computer-based animation instructional method in the teaching and learning of coordination and control had a better impact on students' knowledge and retention of the concepts and therefore has the higher potential of enhancing senior high school Biology students' academic achievement and attitude toward control and coordination concepts with no gender bias.



CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter deals with the introductory part of the research. It comprises the background to the study which discusses the purpose of the research and its relationship with another research. It also covers the problem under investigation and the objectives that the research sought to achieve. This chapter again contains the research questions, significance of the study, delimitations and limitations of the study. It finally embodies the organization of the chapters of the research, Background and Problem Statement

1.1 Background to the Study

The growing recognition of computer-based animation in Ghana marks an important step toward supporting cognitive development and making teaching more revolutionized and improving instructional efficiency. Computer animations have been recognized as a valuable tool in reducing redundancy in education, fostering creativity, and enhancing student engagement (Duncan, 2019). According to Sam (2019), animations facilitate communication by using symbols, drawings, and visual representations to depict complex events, thereby promoting mutual understanding and deeper learning. In this light, computer animations provide a purposeful and engaging approach to education, offering learners guiding principles that enhance intellectual growth (Duncan, 2019).

In Ghana, integrating computer-based animations into Biology education, particularly in second-cycle institutions, has the potential to revolutionize student learning experiences. Zion College, Anloga, a rapidly growing public school located along the Keta Anyanui Road in the Volta Region, serves approximately 1,800 students and is a

key institution in this regard. One of the most challenging topics in the Senior High School (SHS) Biology syllabus is Mammalian Anatomy and Physiology, which requires students:

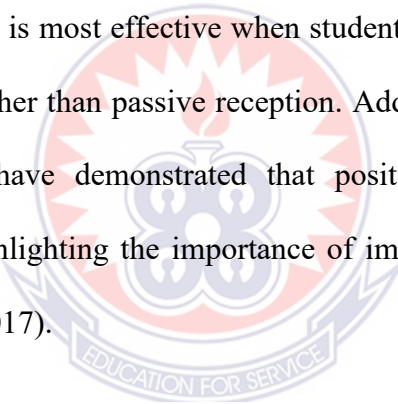
- to understand the structure and function of body organs and survival
- to understand the interrelation between one organ and the other. (Curriculum Research Development Division, Elective Biology Syllabus, 2010, year Two, Section 4, Page 29).

Again by the lesson, the student would make informed contributions on issues concerning health, sex, gender and body functions.

The mastery of this topic is essential for students as it lays the foundation for understanding human health, disease management, and adaptation to environmental changes (Reece, Rowe, & Wiley, 2017). However, traditional instructional approaches in teaching Anatomy and Physiology (A&P) rely heavily on static images and lengthy explanations, often leading to superficial learning and low retention rates (Kind, 2009).

Historically, effective learning in anatomy has emphasized practical, hands-on experiences. Andreas Vesalius, in the 16th century, revolutionized anatomical education by advocating for direct observation and dissection rather than passive textbook learning (Vesalius, 1543). However, despite advancements in science education, traditional teaching methods in Ghana still rely on rote memorization and outdated instructional techniques. Research suggests that students struggle with understanding complex biological processes due to the limitations of these methods, resulting in poor academic performance in national examinations (Schneider & Stern, 2010). such as the West African Senior School Certificate Examination (WASSCE) from 2015 to 2019, Chief Examiner's Report.

Modern students, often referred to as "digital natives," are more inclined toward interactive and technology-driven learning environments, Prensky, M (2001). Their engagement with ICT tools is significantly higher than that of most practicing SHS teachers, who may not fully grasp the pedagogical value of digital tools is significantly higher than that of most practicing SHS teachers, who may face barriers to technological integration due to pedagogical beliefs, training gaps and resource constraint (Tondeur, van Braak, Ertmer, Ottenbreit-Leftwich, 2017). Consequently, traditional text-based and narrative instruction is increasingly ineffective. Studies show that integrating ICT into science education enhances student engagement, motivation, and performance (Brown, 2005). Constructivist theorists, such as Bada (2015), emphasize that learning is most effective when students actively construct knowledge through experiences rather than passive reception. Additionally, behaviorist theorists, including Thorndike, have demonstrated that positive reinforcement strengthens learning outcomes, highlighting the importance of immediate feedback in education (Bruce & Thorndike, 2017).

The logo of the University of Education, Winneba, is a circular emblem. It features a central shield with a book and a torch, surrounded by a wreath. The text "UNIVERSITY OF EDUCATION" is at the top and "WINNEBA" is at the bottom of the circle. A banner at the bottom reads "EDUCATION FOR SERVICE".

The lack of engaging, interactive learning models for Anatomy and Physiology contributes to student disinterest and low retention rates. Many students report difficulty in recalling key concepts despite extensive study efforts. Furthermore, resource constraints, such as the unavailability of dissection specimens due to financial limitations and the COVID-19 pandemic, further hinder hands-on learning experiences. This is inconsistent with Vygotsky's social learning theory, which emphasizes interactive and collaborative learning environments.

Efforts have been made to integrate ICT into Ghanaian education, with initiatives from UNESCO, JICA, ITEC, and AIT aimed at enhancing science and technology instruction. Notably, countries such as Malaysia have successfully leveraged ICT to drive economic and educational advancements (Parong & Mayer, 2018). However, despite policy efforts, ICT integration remains limited in Ghanaian classrooms due to infrastructural and connectivity challenges (Agormedah, Henaku, Ayite, & Ansah, 2020). Studies by Koehler and Mishra (2008) highlight that ICT-based learning environments expand pedagogical resources, improving both teaching and learning effectiveness. Given this context, adopting an animation-based instructional model aligns with global trends in STEM education and could significantly improve learning outcomes in Biology (Ernest, 2022).

1.2 Problem statement

Research indicates that student interest, motivation, and attitudes toward science are closely linked to instructional strategies. The traditional methods employed in teaching Anatomy and Physiology at Zion College have resulted in persistent challenges in student comprehension, particularly in topics related to Control and Coordination (Nervous System).

The persistent underperformance of students in biology, particularly in topics related to Control and Coordination, has been consistently highlighted in the Chief Examiners' Reports from the West African Examinations Council (WAEC). Between the June 2001 and 2014 WASSCE examinations, as well as in comparable assessments, candidates consistently exhibited considerable challenges in understanding the structure and functional roles of the nervous and endocrine systems. Many struggled to accurately explain key physiological processes such as reflex actions, hormone functions, and

homeostatic mechanisms. Common weaknesses identified included: Inability to explain complex biological mechanisms such as the reflex arc and hormonal regulation.

Poor application of knowledge to real-life scenarios and physiological processes.

Frequent misuse or misunderstanding of essential terms like "stimulus," "response," "homeostasis," and "neurotransmitter."

Inaccurate or poorly drawn biological diagrams, often missing crucial labels and lacking clarity.

Difficulty identifying parts of the brain and nervous system and associating them with their correct functions.

Weak articulation and explanation of biological concepts, with many students failing to use the appropriate scientific vocabulary.

To address these issues, the reports have recommended the adoption of improved and engaging teaching methods. In particular, the integration of interactive learning tools—such as simulations, models, and computer-based animations—has been advocated as a means of improving students’ comprehension of abstract and complex biological concepts. Furthermore, attention has been directed toward fostering students’ capacity to apply knowledge, interpret diagrams with accuracy, and develop proficiency in drawing biological structures, while also encouraging the use of diverse learning resources that move beyond reliance on rote memorization.

Despite extensive literature on ICT integration in education, there is limited empirical research on the use of animations in teaching Control and Coordination in Ghanaian secondary schools. This gap underscores the need for an innovative pedagogical approach that leverages digital animations to enhance conceptual understanding and

retention in Biology. Given the proven benefits of animations in facilitating complex scientific learning (Mayer & Anderson, 1992), this study aims to investigate the effectiveness of computer-based animations in improving student performance in Control and Coordination among SHS Form Two Biology students at Zion College.

The overarching goal of this study is to determine whether integrating animations into the teaching of Anatomy and Physiology can significantly enhance student engagement, comprehension, and academic performance. As students increasingly prefer digital learning tools, this research seeks to bridge the gap between traditional pedagogy and modern educational demands, ultimately contributing to improved STEM education in Zion College, Anloga.

1.3 Purpose of Study

The purpose of the study was to investigate the learning outcomes with computer-based animation in the teaching and learning of Control and Coordination” to second-year Biology students in Zion College.

1.4 Objectives of Study

The objectives of the study were to:

1. establish the effect of computer-based animation in the teaching and learning of control and coordination concepts Biology.
2. examine the extent to which the use of computer-based animation instructional method improves students’ attitude toward control and coordination concepts.
3. determine the extent to which the use of computer-based animation enhances students’ long-term retention of the control and coordination concepts.
4. ascertain the effect of computer-based animation method on gender difference on students’ academic performance in control and coordination concepts.

1.5 Research Questions

The following research questions were used:

1. What is the effect of computer-based animation in the teaching and learning of control and coordination concepts?
2. What is the extent to which the use of computer-based animation instructional method improves students' attitude toward control and coordination concepts?
3. To what extent does the use of computer-based animation enhance students' long-term retention of the control and coordination concepts?
4. What is the effect of computer-based animation method on gender differences students' academic performance in control and coordination concepts?

1.7 Significance of the Study

If the null hypothesis is rejected, the results of this study will provide a solid basis for incorporating computer-based animation into the teaching and learning of control and coordination in anatomy and physiology courses, by enhancing Zion College students understanding and engagement in this specific topic. This will, in the end, prepare the students to enter and excel academically in STEM career-related institutions. It will also help build such capacity in learners to have relevance for technology in the global village. It will also motivate the curriculum planners to use animation as a tool in training institutions to help students have the flair for integrating ICT models in teaching.

1.8 Delimitation of the Study

The study was delimited to SHS Two Science and Home Economics students who study Biology as an elective subject in Zion College. Again, only an aspect of Biology and

Anatomy, Control and coordination in section five, unit six of the SHS elective Biology syllabus was used.

1.9 Limitations to the Study

Limitations are conditions beyond the control of the researcher that would put restrictions on the conclusions and inferences drawn from the study and its applications to other situations (Best & Khan, 1989). The study was limited to the use of computer-based animations.

1.11 Organization of the Study

This research is organized into five (5) chapters. Chapter one deals with the Background to the Study, Statement of Problem, Purpose of the Study Research Objectives and Research Questions, Significance of the Study, Limitation and Delimitation of the Study and a brief discussion of how the report is organized.

Chapter Two gives an insight into the review of literature related to the study and addresses several related sub-themes.

Chapter Three discusses the methodology adopted for the study. It looks at what research method presents the research approach, setting, the population of the study, data and data source, method of collecting data, the technique of analyzing data and research procedure.

Chapter Four deals with the presentation and analysis of the data gathered for the study. The final chapter provides the summary, conclusions of the study, recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

The chapter presents a theoretical perspective, and empirical evidence for the project under investigation, a review of related literature to this study. It covers the following: the theoretical framework that underpins the study, computer-based animation in education, learning anatomy and physiology; a good gatekeeper course, motivation of students, teacher understanding complex systems, the academic performance of students in Biology and analysis of the WASSCE result. This chapter gives details about articles written concerning this study. However, the literature review examines articles, books, and other sources relevant to a particular area of research. The survey should enumerate, describe, summarize, objectively evaluate, and clarify previous research on the project (Machi & McEvoy, 2009). Literature review acknowledges the contributions of previous researchers and demonstrates to the reader that the study has been thoughtfully conceptualized. According to Machi and McEvoy (2009), the literature review constructs a “landscape” that provides a comprehensive understanding of developments within the field. This intellectual landscape illustrates that the researcher has critically engaged with, and integrated, a substantial proportion of relevant prior studies into the current investigation. However, when writing a literature review, the purpose is to tell the reader what facts and ideas have been entrenched on the subject at hand and their positivity and negativities. The study also deals with the educational problem of a limited number of students' understanding of complex systems such as Control and Coordination from the perspective of the teacher and the argument advanced for an intervention in the instructional practice of teachers. A summary of the content and the conceptual framework.

2.1 Theoretical Framework

The theories under which science is learnt are a cohesion of the global theories, cognitivist, behaviorist and constructivist perspectives.

A theory is a contemplative and rational type of abstract or generalizing thinking about a phenomenon or the results of such thinking (Alkali, 2009). Theories are ideas, facts, and principles used to describe a given concept (Bedford & Alkali, 2009). Theories are developed to provide explanations and deeper understanding of phenomena, frequently questioning and extending existing knowledge while operating within defined critical assumptions. A theoretical framework is an essential component of research, shaping the quality and scope of investigations (Holliday & Anderson, 2006). This framework strengthens the study in several ways: (a) an explicit statement of theoretical assumptions allows readers to evaluate them critically, (b) it connects the researcher to existing knowledge, (c) it provides a basis for hypotheses and research method choices (Herek, 2010), and (d) it forces the researcher to address questions of why and how, enabling generalization beyond mere description. However, having a theory limits the extent of generalization. This research design employs aspects of behavioral and cognitive theories but is primarily based on constructivism, which posits that knowledge is acquired through social interaction (Vygotsky, 1978). Teaching science subjects often relies on constructivist theory, and this study incorporates a socialist perspective and inquiry-based learning.

2.2 The Theory of Constructivism

Constructivism is the theory behind how learning takes place in the cognitive structure of the learner (Savery & Duffy, 2006). According to this theory, the challenges and difficulties confronting classroom teachers are the reform strategies, curriculum,

instructions, and assessment engineered around the constructivism theory (Krajcik, Blumenfeld, Marx, & Soloway, 1994). These are formed by different elements, including cognitive capacity and the nature of knowledge in our traditional classroom (Kim, 2005). As a theory of learning, constructivism is pertinent to this study since it provides a framework for understanding how teaching and learning processes take place (Richardson, 1997). Watson (as cited in Brown & Zhou, 2015), a behavioral psychologist, posits that most of a person's behavior determinants are learned, although they may possess intrinsic behavior. Thorndike's mechanistic learning theory (as cited in Cziko, 2000) suggests that learning is a process of selecting and connecting solutions to escape the "puzzle box" of uncertainty. Constructivists like Lev Vygotsky and David Ausbel also believe that knowledge is constructively acquired by the learner through social interaction (Cakir, 2008). Teaching science subjects is often based on this perspective.

When students encounter something new, they have to reconcile it with what is already in their long-term memory (LTM) (Oliver, 2000). The new knowledge may be discarded as irrelevant by the thalamus reticular formation of the brain adjusted and the knowledge is internalized. The teacher therefore has an onerous task to understand the preconceived ideas of his students and guide them by dropping the right kind of cues when venturing into the teaching of a new concept (Oliver, 2000). Explanations and demonstration of concepts by teachers serve as an environmental input (animation, videogames, computer animations etc.) for students. The practice of acquired skills, reinforced by corrective feedback when necessary, facilitates learning. Nonetheless, cognitive theories argue that instructional factors alone are insufficient to explain student learning (Pintrich, Cross, Kozma, & McKeachie, 1986). Rather, the ways in which students engage with information—through attending to it, rehearsing,

transforming, coding, storing, and retrieving—are considered critically important (Pintrich et al., 1986). Learner's thoughts, attitudes, and beliefs are the factors that an instruction should be purposed to work on at the same time as getting through with learning (Greenhow, Robelia, & Hughes, 2009). The constructivists place prominence on the role of memory in knowledge acquisition. In their assertion, learning is equated to encoding and retrieving information in response to relevant cues (systematic presentation of information in an organized manner, relatable with the known, using meaningful means to retrieve it) that activate appropriate memory structures (Newcombe & Huttenlocher, 2003). One tenet of all constructivist roles is that learning has to be an active process (Tam, 2000); hence a learning environment under this theory must provide an opportunity for active learning (Tam, 2000). The following characteristics are essential in such an environment:

1. Knowledge is collaboratively constructed and shared between teachers and students.
2. Authority and responsibility for learning are jointly exercised by both teachers and students.
3. The teacher's role is redefined as that of a facilitator, providing appropriate guidance and support.
4. Learning takes place in small, heterogeneous groups that promote interaction and collaboration.

2.3 Constructivism and Classroom Practice in BIOLOGY Education

A constructivist instructor and a constructivist's learning environment are identifiable from the normal traditional teacher and his four-walled classroom. The following identifies the latter without prior direction;

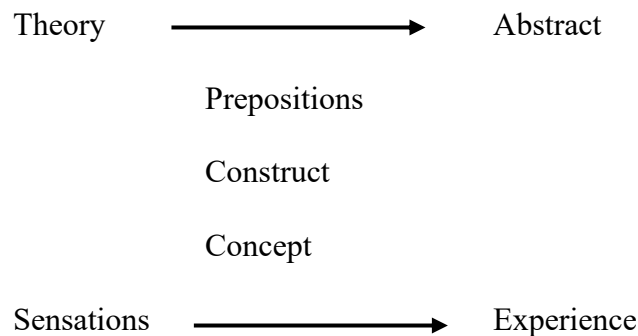
- Learners are actively involved

- The environment is democratic
- The activities are interactive and student-centered
- And teacher facilitates a process in which participating students are made to be responsible and autonomous.

According to Spiro (2006), a constructivist classroom provides students with the time and opportunity to develop a deep understanding of content by forming mental connections that enable them to apply knowledge in various contexts. In this setting, the teacher acts as a facilitator, allowing students to take an active role in their learning, move freely, and utilize time flexibly (Olojo, Adewumi, & Ajisola, 2012). Assessment is focused on individual progress and peer comparison, rather than formal testing (Olojo et al., 2012). Teachers recognize and incorporate students' experiences, perceptions, and prior knowledge into the lesson (Olojo et al., 2012). This inquiry-based approach to science learning, as advocated by Keys and Bryan (2001), fosters a deep understanding of concepts. Moreover, the socialist perspective aligns with the constructivist environment, emphasizing the importance of arranging teaching elements to promote healthy interactions, leading to invention, meaning-making, and rich learning experiences (Keys & Bryan, 2001).

2.4 Conceptual Framework

The intervention, and the independent variable, computer- based animation is purposed for removing confusion as it connects other variables and the cognitive structure to arrive at an equilibrium as illustrated in the model below,



In examining theoretical discussions, it is essential to consider the interrelationship among concepts, constructs, and propositions in relation to theory. Beginning with concrete experiences and sensations, concepts serve as labels assigned to events, enabling distinctions between occurrences and facilitating connections across past, present, and future experiences. When grouped together, concepts form higher-order units of thought referred to as constructs (Silver, 1983). For example, Intelligence Quotient (IQ) is a construct that integrates concepts such as age—the duration of an individual’s life, and intelligence; the extent of knowledge acquired (Silver, 1983). At a higher level of abstraction, we encounter propositions. Propositions are expressions of the relationships among several constructs. Accordingly, researchers use a set of propositions that are logically related to form a theory. Whenever a theory is developed, a highly complex task has been accomplished; an abstract thought process is formed devoid of the world’s immediate sensations and experiences even though they are needed to understand the world. The building blocks above give a pictorial understanding of a theory.

However, another school of thought, constructivist learning theory provides a robust foundation aside sensations, for understanding how learners acquire, process and retain knowledge constructivist learning theory provides a robust foundation for

understanding how learners acquire, process, and retain knowledge. At its core, constructivism emphasizes that learners are not passive recipients of information but active participants who build meaning through interaction with their environment, peers, and instructional tools (Bruner, 1960; Piaget, 1972; Vygotsky, 1978). Education, from this perspective, should focus on problem-solving, critical thinking, and the connection of new knowledge to existing frameworks of understanding (Fosnot, 2013).

A central contribution to constructivist thought is Vygotsky's (1978) zone of proximal development (ZPD), defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers" (p. 86). The ZPD highlights learning as a dynamic and socially mediated process. When learners receive appropriate support, through scaffolding, guidance, or collaboration, they are able to achieve tasks that would otherwise be beyond their independent capability. Over time, these external supports are gradually internalized, transforming into self-directed strategies and higher mental functions (Leontyev, 1981; Rogoff, 1990). This movement from external guidance to internal regulation illustrates the social origins of cognition and reinforces the view that meaningful learning emerges from active, supported participation.

Building on this, the formation of educational theory can be understood as a progression from concepts to constructs and ultimately to propositions. Concepts such as engagement, prior knowledge, and retention are refined into constructs when clearly defined for study and analysis (Kerlinger & Lee, 2000). At a higher level of abstraction, propositions describe how these constructs interrelate, forming the explanatory power of theory (Dubin, 1978). Within constructivism, such propositions consistently stress

that learning occurs when learners engage actively, connect new material to prior experiences, and internalize knowledge for long-term use.

The interplay of the variables in this study, computer-based animation, student engagement, prior knowledge, and retention, can thus be understood within the constructivist framework. Computer-based animation functions as a mediating tool that stimulates engagement by making abstract biological processes visible and interactive (Mayer, 2009). Engagement, in turn, serves as a bridge to the activation of prior knowledge, allowing learners to connect new information to existing schemas (Ausubel, 1968). This integration results in deeper processing, which strengthens retention over time. Empirical evidence supports this sequence, showing that instructional media that enhance engagement also promote long-term recall when learners meaningfully integrate new and prior knowledge (Fredricks, Blumenfeld, & Paris, 2004; Clark & Mayer, 2016).

Taken together, these relationships embody propositions derived from constructivist theory:

1. Instructional tools that promote active engagement facilitate knowledge construction.
2. Engagement with learning materials fosters the activation of prior knowledge.
3. The meaningful integration of prior knowledge and new learning supports stronger retention.

Thus, constructivism provides both the theoretical logic and the structural framework for this study. The ZPD and internalization explain the mechanisms of guided learning,

while the interplay among engagement, prior knowledge, and retention illustrates how the intervention, computer-based animation, operates within this paradigm to improve student outcomes. See Appendix D as summary interactive activity which reinforces the learning outcome.

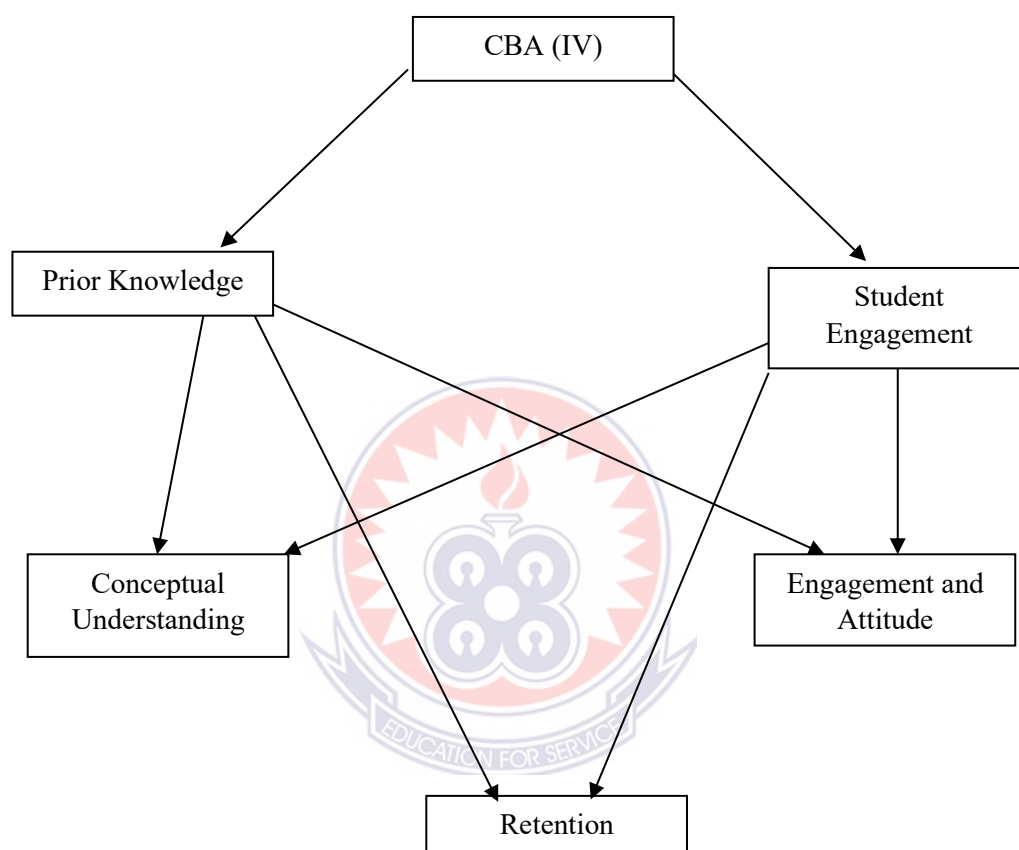


Figure 1: Relationship between the independent variable CBA and dependent variable control and coordination

2.5 The Demand of the Senior High School Syllabus

Students are expected to observe models, diagrams, and charts of the eye to identify their various parts. They are to discuss the structure and functions of these sensory organs, and draw and label each part. Eye defects such as myopia, hypermetropia, presbyopia, and astigmatism should be discussed along with their corrections.

Learners should also identify the organs of the endocrine system, name the hormones produced by each, describe their target organs, and explain the effects of these hormones. Additionally, students are to discuss the consequences of hormone over-secretion or under-secretion. As part of practical work, a chloroformed mammal (e.g., rat or rabbit) is to be dissected for the identification and drawing of internal organs in their natural arrangement.

The topic, “Control and Coordination” should be introduced through brainstorming. Learners should observe models or charts of the nervous system to identify its various parts. They should locate the brain and discuss how it is protected, as well as identify and discuss the functions of its regions. Students are also expected to examine spinal cord slides under a microscope, label its parts, and describe its functions. Furthermore, they should observe and analyze charts or diagrams of neurons, draw and label a neuron, and discuss how its structure relates to its function.

While the outlined approach offers a structured and content-rich exploration of biological systems, it largely relies on passive observation and traditional practical methods. It does not fully meet the expectations of 21st-century teaching and learning, which emphasize interactivity, digital literacy, and learner-centered engagement. The absence of ICT tools; particularly multimedia and animation; limits students' opportunities to visualize complex processes dynamically, interact with content, or apply knowledge creatively.

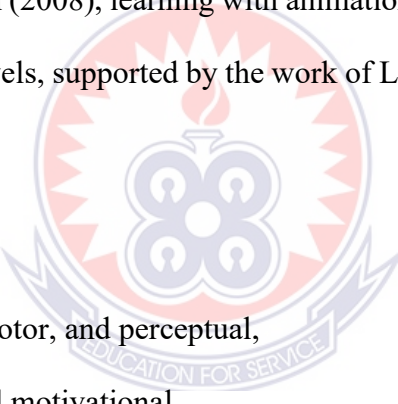
To bridge this gap, computer-based animation presents a compelling alternative. It not only brings abstract biological processes to life but also fosters deeper understanding through visual storytelling and interactivity. Such methods are more aligned with how

today's learners absorb and apply information, making the learning experience both engaging and effective.

2.6 Animation in Education

Animations, as a form of dynamic representation, illustrate processes that unfold over time, such as the movement of molecules or electrical charges (Rakiyah, 2019). Since the early 1980s, animations have been increasingly integrated into educational technologies, with their availability and sophistication expanding in tandem with advancements in both software development and hardware capabilities for their creation and use (Rakiyah, 2019).

According to Ainsworth (2008), learning with animations can be understood through at least six explanatory levels, supported by the work of Lowe and Schnotz (2008). These levels include:

- 
- a) expressive,
 - b) cognitive, motor, and perceptual,
 - c) affective and motivational,
 - d) strategic,
 - e) metacognitive, and
 - f) rhetorical.

Building on earlier work, Lowe and Schnotz (2014) proposed a three-level framework of representational learning, which Ainsworth (2008) extended to six levels through evidence from empirical studies and theoretical perspectives in multimedia learning. These levels range from basic representational features to socially and culturally influenced dimensions. Although this progression may appear hierarchical, it does not

imply a strictly linear dependency, as each level can function independently of the others.

In this context, each section of the review will examine theories, empirical findings, and research associated with a specific explanatory level (e.g., cognitive, affective) in the domain of learning with representations, such as diagrams, text, and animations. The discussion will encompass studies on both learning through provided animations and the construction of animations, acknowledging that the depth and breadth of research differ considerably across the identified levels.

2.7 Expressive Explanations

Stenning and Oberlander (1995) introduced an explanatory level that emphasizes the intrinsic properties of representations and their influence on the computational demands required to draw inferences. They argued that the value of graphical representations, such as set diagrams, lies in their restricted capacity for abstraction, which helps reduce the cognitive search necessary to reach accurate inferences. However, this limited expressiveness also creates challenges when representing abstract concepts, such as disjunctions, within graphical forms (Ainsworth, 2008).

When applied to animations, the expressive level of analysis draws attention to the issue of temporal constraining, as animations, being transient in nature, cannot remain ambiguous regarding time (Ainsworth, 2008). This constraint may compel activities to be presented in a fixed sequence, potentially leading to misconceptions. Moreover, because animations must display all components of a dynamic process, learners may form incorrect conclusions about elements not visible in the animation (Ainsworth, 2008).

For instance, an animation depicting blood flow through the heart might cause learners to believe that only one side of the heart fills with blood at a time if the animation highlights one side exclusively. To address this issue, animations must attempt to depict all relevant aspects of the phenomenon simultaneously. However, this creates a further challenge, as learners may struggle to identify which features of the animation are most salient at a particular moment (Ainsworth, 2008).

2.8 Cognitive, Perceptual and Motor Explanation

This level, as outlined by Felin et al. (2012), considers the interplay between the form of a representation and an individual's cognitive capacities, prior knowledge, and skills. The effectiveness of any representation is therefore shaped not only by the universal constraints of human cognitive architecture but also by the learner's unique experiences. Representations are thus assessed according to their ability to offset cognitive limitations—particularly those related to memory—and to minimize the mental effort required for learning from animations (Ainsworth, 2008).

2.9 Cognitive Explanations

The widespread intuitive appeal of animation is fundamentally grounded in cognitive explanations, with many scholars framing their arguments at this level of analysis. Central to this perspective is the Congruence Principle proposed by Scaife and Rogers (1996), which posits that the structure and content of an external representation should align with the intended internal mental representation. From this standpoint, animation emerges as a particularly appropriate medium for depicting dynamic processes, such as the circulation of blood through the heart.

Cognitive effort, as described by Larkin and Simon (1987), involves search, recognition, and inference operations. Diagrams can reduce cognitive effort by

preserving geometric and topological information, exploiting perceptual processes, and minimizing search and recognition requirements. Zhang and Norman (1994) demonstrated that representations with explicit constraints can reduce cognitive effort by leveraging external perceptual processes instead of internal cognitive operations.

The most comprehensive cognitive theory of animation in learning is Richard Mayer's (2001) theory, which posits three fundamental assumptions:

1. Separate channels for processing visual and verbal representations
2. Limited processing capacity in each channel
3. Meaningful learning results from actively constructing knowledge through selection, organization, and integration of new material with existing knowledge

Mayer's cognitive theory of multimedia learning provides an important foundation for understanding the benefits of animation in education (Mayer, 2001). According to this theory, narrated animations are particularly effective because they enable the presentation of complex information in ways that make optimal use of the limited capacity of the human cognitive system. Mayer termed this the multimedia principle, which states that "students learn more deeply from animation and narration than from narration alone" (Mayer, 2001, p. x), a claim supported by numerous empirical studies. For instance, Mayer and Anderson (1991) demonstrated that college students who were presented with an animation of a bicycle tire pump accompanied by narration performed significantly better on post-tests than those who received narration alone.

Further insights into the cognitive benefits of animation are provided by Schnotz and Rasch (2005), who distinguish between two key functions. The first, the enabling function, posits that animations can present information unavailable in static pictures,

thereby encouraging additional cognitive processing. The second, the facilitating function, suggests that animations help learners construct dynamic mental models by supplying external supports that ease cognitive processing.

Bétrancourt (2005) identified an additional cognitive role of animation: the creation of cognitive conflict. For example, learners often hold naive physical misconceptions, such as believing that objects of different weights fall at different speeds. An animation showing such objects falling simultaneously can evoke cognitive dissonance, thereby promoting conceptual change (Bétrancourt, 2005; Chinn & Brewer, 1993).

Despite these advantages, the cognitive benefits of animation are not guaranteed. Price (2002) emphasizes that while animations can make dynamic processes more explicit, their effectiveness depends on design and learner interaction. In line with this, Tversky (2002) proposed the Apprehension Principle, which asserts that external representations must be easily and accurately perceived and understood in order to support learning. However, Tversky also highlighted cognitive constraints in processing dynamic animations, particularly the potential to overload working memory. Because animations are transient, learners must retain information temporarily while integrating it with new material, a process that can hinder comprehension if memory demands become excessive (Stenning & Oberlander, 1995).

In contrast, persistent media like pictures can reduce the cognitive load on working memory (Sweller et al., 1998). Cognitive Load Theory (Sweller et al., 1998) suggests that animations can impose a high extraneous cognitive load, exceeding learners' cognitive capacity and hindering effective processing (Lowe, 2004). However, strategies like segmenting animations, allowing learner control, and directing attention to key elements can reduce extraneous load and enhance learning (Paas & Ayres, 2014).

Moreover, animations can lead to passive observation rather than active processing and understanding, especially when depicting dynamic systems (Lowe, 2004). Empirical evidence supports this prediction, showing that learners who received pictures performed better on circumnavigation questions than those who received animations (Schnotz & Rasch, 2005).

2.10 Motor Explanations

Although limited research has addressed the role of physical action in learning with animations, the significance of motor activity has long been emphasized in educational and developmental theories (Piaget & Inhelder, 1969; Bruner, 1966). Piaget and Inhelder (1969) believed that motor actions formed the basis of all learning, with infants beginning with sensorimotor representations that develop into symbolic representations. Bruner (1966) also emphasized the role of action in learning, describing how knowledge is acquired and stored through enactive, iconic, and symbolic representations. These theories have received renewed attention in the context of embodied cognition and haptic and tangible interfaces (Martin & Schwartz, 2005). Empirical evidence indicates that physical action can facilitate learning through mechanisms such as induction, offloading, repurposing, and physically distributed learning (Martin & Schwartz, 2005). This suggests that learning with animations may be shaped by a motor level of explanation, whereby animated and interactive graphics enable learners to engage with the learning environment in ways comparable to physically distributed learning (PDL). Nevertheless, further research is required to clarify the specific role of physical action and gesture in the context of learning with animations.

In the present study, the rhetorical dimension was excluded, as the investigation focused specifically on the use of animation as a pedagogical tool for teaching and learning

biological concepts. Given that the research objective centered on assessing knowledge acquisition, comprehension, and retention, the rhetorical function of animation though significant in media and communication studies was deemed less directly relevant to instructional effectiveness within the biology classroom. Consequently, it was intentionally omitted from the analysis.

2.13 Advocates for Interactive Multimedia

Many have advocated for effective interactive multimedia and its use in Senior High School. Accra Institute of Technology, AIT, in collaboration with MOE, has made strides in that regard. The goal was to train teachers to integrate ICT into teaching and learning and create platforms to build interactive instructional lessons for teaching and learning. Many impressive sites like you-tube videos, animations, sounds and images with advancing levels of interactivity, assessment and intelligently planned content, interactive multimedia could be used to explain particularly intricate processes that would otherwise be difficult to use the conventional instructional method to execute it. It's (interactive multimedia) use, therefore, is not to entirely do away with the traditional pedagogy but rather to balance it to improve comprehension. While at it, it changes the negative perceptions about anatomy. According to Brown (2003), there are numerous examples of faculty effectively incorporating interactive multimedia into their teaching practices. Prensky (2003) has also advocated for the use of digital games in education, highlighting their potential to develop critical thinking skills. Moreover, Schunk (2008) has emphasized the importance of motivation in engaging students in science learning, suggesting that highly motivated students are more likely to be academically inclined in mathematics and sciences. Romano (2003) has also stressed the need for technology integration in education, noting that traditional teaching methods often favor left-brain thinkers and may neglect right-brain thinkers. This

research aims to address these imbalances through the development of effective animation modules in Biology, with the goal of sustaining student interest, promoting learning, and improving academic performance.

2.14 Animation as an Interactive Multimedia in Education

The increasing availability of computers and presentation software such as Microsoft PowerPoint, Apple Keynote, and Xerte has contributed to the widespread integration of animations as instructional tools in classrooms worldwide (Kim, 2007). Educators are increasingly encouraged to embed technology into their pedagogical practices to engage students who are accustomed to technology-rich learning environments. As a result, traditional methods such as lectures, worksheets, and textbook-based instruction are being supplemented or, in some cases, replaced by virtual lectures, web-based learning, project-based approaches, and student-generated multimedia presentations (Sanger, 2001).

Instructional animations are particularly valued for their capacity to depict temporal changes, positional shifts, and transformations with clarity (Stith et al., 2004). Unlike static textbook illustrations, which often rely on symbolic markers such as arrows to indicate change, animations demand less interpretation and inference, thereby reducing the likelihood of learner confusion (McClean, 2005). Their dynamic and visually engaging nature, enhanced by movement and color, helps sustain learner attention and contributes to their broad appeal (Kim, 2007). Furthermore, animations can accommodate diverse learning styles: visual learners benefit from transitional imagery, auditory learners from integrated narration, and kinesthetic learners from interactive animations (Stith et al., 2004).

Despite these advantages, animations are not without limitations. Careful design and selection are essential, as animations that are excessively rapid or overly complex may hinder rather than facilitate understanding (Tversky, 2002). In addition, technological constraints, such as equipment failures or software malfunctions, pose practical challenges that can compromise instructional effectiveness.

2.15 Teacher Understanding and Subject Matter

Subject matter in this context is the A and P to enhance students' interest in A and P, teachers' understanding and mastery of the subject matter and instructional practice. There are several aspects of knowledge, but only the subject matter and pedagogical content that is linked often to teacher understanding (Bada, 2015). That notwithstanding, the plethora of knowledge comes with a lot more; class management skills, class environment, learning styles, subject matter can misrepresent the content to their students, causing them to misunderstand (Bada, 2015). This reflection suggests that the mental modules of the teachers have an impact on the students' understanding (Bada, 2015). In a comprehensive review of research on teachers' knowledge of anatomy and physiology, when teachers have expertise, they can skillfully engage the students in the class (Gottlieb & Oudyer, 2018). To engage students who are disengaged in learning science is that which stems from an internal state that directs and sustains science learning behavior (Schunk et al., 2008). Highly motivated students are more likely than others to be academically inclined in Mathematics and Science classes (Kim, 2007) and they are also more actively involved in their learning (Schnuk, 2008).

2.16 Computer Animations

According to Fishwick (2016), computer animation is defined as the field concerned with designing a model of a real or theoretical system, implementing that model on a

digital computer, and analyzing the resulting output. An animation model is a mathematical representation that computes the effects of specific inputs and decisions on outcomes. Such models can be constructed using a programming language, logical statements, or spreadsheet-based formats. Regardless of the mode of expression, the output of animation models is contingent upon uncertain inputs; consequently, these models are composed of uncertain variables and functions (Animations on the Internet).

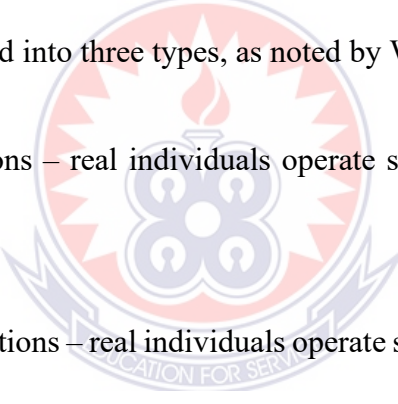
In contrast, emulations replicate a system such that the second system behaves in an identical manner to the first (Agormedah et al., 2020). For example, an Animations Models in Education program may enable printers to emulate HP LaserJet printers, thereby allowing them to function with software intended for HP hardware (Agormedah et al., 2020).

Computer animations are noteworthy for their interactivity and their capacity for representation in diverse forms (Kim et al., 2007). Their use is now considered essential for pupils and students from varied backgrounds and knowledge levels, as they help to overcome barriers and expand educational possibilities. This approach facilitates a student-centered education tailored to individual needs. E-learning is widely regarded as one of the most effective contemporary learning environments, with the computer serving as the central tool connecting learners to lifelong education (Kim et al., 2007). Interactive animations represent the optimal method for integrating animation models into education, thereby fully leveraging their potential.

Computer animations function significantly as both cognitive tools and learning objects (Sanger, 2001). Computer literacy is a fundamental component of modern basic education, positioning the computer, with its vast capabilities, as a primary driver of experiential and lifelong learning. These animations have become invaluable for

modeling natural systems in physics, chemistry, and biology, as well as human systems in economics, social sciences, and information science (Sanger, 2001). A pertinent example of their utility is found in network traffic animations (Sanger, 2001), where the model's behavior changes with each run based on the initial parameters set for the environment.

Computer animations are frequently characterized as human out-of-the-loop simulations. The educational application of computers is multifaceted; they can act as an instrument, an object of study, a support tool, or a comprehensive learning environment. When used as a learning environment for educational purposes, these applications are termed computer-assisted learning (CAL). Such "training simulations" are generally categorized into three types, as noted by Wiki:

- 
- "Live" simulations – real individuals operate simulated equipment in the real world.
 - "Virtual" simulations – real individuals operate simulated equipment in a virtual reality environment.
 - "Constructive" simulations – simulated individuals operate simulated equipment in a virtual reality environment.

It is critical to note that in all three categories, users interact with simulated equipment, a feature that underscores the key distinction between simulation and experimentation, as discussed by Keränen, Ott, and Kärkkäinen (2009). Information science incorporates all the aforementioned computer uses and simulation categories, which is vital for advancing lifelong learning, particularly through the crucial element of interactivity (Brown & Zhou, 2015).

2.17 Animations and Learning

Animation models serve as a valuable tool within the education system, applicable from primary through secondary to high school levels, fulfilling both instructional and engagement functions. At the high school level, specific animation models can facilitate research, inform decision-making, and support the development of courses related to animation modeling itself. These programs offer significant advantages, including enhanced validity and credibility (Cant & Cooper, 2010).

The benefits of animation model programs include:

- The capacity to experiment with various phenomena or events.
- The ability to concretize abstract concepts, particularly in fields like information science.

This aligns with the perspective of Min (1993), who stated that “Animations are excellent discovery learning techniques that often offer insight or 'gestalts' not gained through more traditional didactic methods.” It is relevant to note that this modern application of animation encompasses discovery learning, which is among the oldest forms of instruction. However, these models also present disadvantages, the most significant of which concerns credibility; if an animation's credibility is questionable, the reality it presents becomes problematic. For instance, a computer animation model developed for the National University of Tres de Febrero enabled the forecasting of educational policy impacts across cultural, technological, social, educational, and economic contexts prior to their real-world implementation. This allowed for an assessment of whether institutional aims in planning, teaching, research, and knowledge transfer were being met.

The process of learning to create animation models involves three fundamental subprocesses: model design, model execution, and model analysis. This domain encompasses a wide range of concepts, including system modeling, technology, safety, testing, training, sourcing valid information, understanding key behavioral characteristics, making appropriate simplifications, and ensuring the fidelity and validity of both outcomes and the educational process itself (Stancic, 2007).

A primary strength of animation models is their capacity to situate students in scenarios they will encounter in their professional futures. For example, models can demonstrate:

- Computer assembly and optimization.
- The organization and fine-tuning of a network or web server based on user load.
- Software operation procedures.
- Protocols for handling fragile archival, library, or museum materials, including their preservation (e.g., through deterioration animations under various environmental conditions) and the restoration of artworks.
- The organization and digitization of collections.

This brief list illustrates the varying levels of expected knowledge these models can address. On educational animation platforms, students utilize simulations to comprehend social processes, simulate life events, and develop critical thinking strategies by identifying, recording, and analyzing facts, ideas, and events. Other applications allow students to create personal journals that simulate life in a specific global region, thereby emphasizing individualized learning and showcasing the

accessibility of education through distance and animation-based methods (Wankel, 2009).

Interactive educational animations, such as the "Electronic United Nations," enable primary and secondary students to engage in role-playing exercises where they create a classroom country complete with a constitution, economy, and judicial system. Students then collaborate with other "countries" to address global issues, learning about leadership, politics, and the importance of law and order (Graber & Smith, 2005).

Dynamic animations, which respond to input signals, are used in simulation games, scientific research, and practical applications like weather forecasting and logistics (Kincaid, 2002). Advances in computer technology have further enabled the creation of sophisticated three-dimensional dynamic models, which are particularly useful for teaching animation principles, process construction, and visualization (Zukerman & Litman, 2001).

The utility of animation models extends to language processing, aiding in tasks such as documenting simulations and synthesizing models using controlled English (Stancic, 2007). Furthermore, they are extensively employed in medical education to teach new therapies, treatments, and diagnostic procedures, and even to explore the effects of placebo drugs (Kim, 2007).

2.18 Animations Models and Curriculum

Learning tools, which are generally integrated within a comprehensive curriculum, are designed to stimulate student motivation and encourage deeper exploration of subject matter. Contemporary educational institutions increasingly provide advanced learning tools, frequently in the format of electronic teaching packages accessible via online

platforms. These digital resources are instrumental in promoting both online and lifelong learning.

However, it is critical to acknowledge the significant limitations inherent in virtual learning environments that are inadequately designed. Poor usability, a lack of pedagogical structure, and ineffective user engagement can severely undermine their educational potential and hinder the learning process. Relying solely on animation as a visual learning method can be a setback, as it may not provide a realistic understanding of the subject matter (Barker, 2005). Practical learning methods, such as writing or project-based learning, can enrich the curriculum and better suit the needs of today's society. Computer animations, a key aspect of information science education, utilize computers as a familiar tool to engage learners (Jamie, 2022). Implementing animation models in education can:

- Provide information or visualize phenomena
- Facilitate practice and learning (e.g., language learning)
- Assess knowledge and offer individual feedback

A well-designed curriculum should incorporate a diverse range of learning tools, considering the target audience and their characteristics. Animation models can be applied across various study levels, with or without prerequisites, to test students' ability to apply acquired knowledge (Milrad, 2002).

2.19 Attitudes of Learners in Using the Computer-based Animation in Teaching and Learning

An attitude is characterized as a psychological tendency to evaluate a particular entity with a certain level of approval or disapproval. In essence, attitudes reflect an individual's favorable or unfavorable responses to various situations or objects (Eagly

& Chaiken, 1993). Within educational settings, attitudes are frequently developed through direct experiences in teaching and learning environments. The structure of an attitude is understood to comprise three principal components: a cognitive element involving beliefs and thoughts, an affective element concerning emotions and feelings, and a behavioral element pertaining to predispositions to act in certain ways. According to Mensah, Okyere, and Kuranchie (2013), cognitive components refer to an individual's beliefs and thoughts about an object, affective components represent the associated feelings, and behavioral components encompass the person's responses and behaviors towards the object. When utilizing animation as an instructional method, its design should positively influence learners' beliefs and feelings, thereby enhancing their learning experience and benefits. Learners acquire knowledge in diverse ways and to varying degrees of success, such as through reading, memorization, problem-solving, observation, video watching, and experimentation. Software designers can employ various techniques, like mnemonics and chunking, to present information and organize content in a way that boosts knowledge retention.

To effectively integrate computer-based animation applications in the classroom, a structured instructional approach is necessary, breaking down learning into sequential, incremental activities that target specific skills (Pachler & Leask, 2014). The software assumes a teaching role, providing "drill and practice" exercises followed by immediate feedback on students' work. Most digital web-based tools align with behaviorist learning theories, emphasizing repetition and practice opportunities for learners. The impact of computer-based animation tools on learners' attitudes towards Biology learning, particularly Control and Coordination, is significant. Attitudes are shaped by three behaviorist learning theories: classical conditioning, operant conditioning, and observational learning (Mensah, Okyere, & Kuranchie, 2013). Skinner's theory of

operant conditioning posits that the application of positive reinforcement serves to increase the probability of a behavior recurring (Skinner, 1953). This perspective stands in contrast to the views of cognitive psychologists such as Piaget, for whom learning constitutes an internal process that is not directly observable (Piaget, 1968). Cognitive theories, including the information-processing approach, focus instead on the mental capacities to process, store, and later retrieve knowledge (Slavin, 2012).

Constructivist theory further expands this view by proposing that learners actively build their own understanding by integrating prior knowledge with experiences in interactive environments (Schunk, 2012). Within a constructivist framework, the pedagogical dynamic shifts from a teacher-centered to a learner-centered model. In this setting, the instructor assumes the role of a facilitator who guides learners, ensures situations are relevant to their experiences, and helps them develop metacognitive awareness of their own learning strategies.

A fundamental distinction exists between behavioral learning theories, which are predicated on observable actions, and cognitive theories, which emphasize internal constructs like beliefs and attitudes (Slavin, 2012). Consequently, the process through which learners construct knowledge using ICT tools can be seen as a synthesis of both behavioral and cognitive principles. Teachers and educational software demonstrate new concepts—a process learners then practice and receive feedback on, aligning with behavioral methods. Simultaneously, the learners' perceptions of their own capabilities, which are cognitive in nature, directly influence their performance. This interconnection makes it essential for educators to carefully consider learner attitudes when designing and implementing lessons (Schunk, 2012).

Lastly, the affectional drive motivates us to show emotional nurturance and develop a positive attitude towards life (Barnett, 2017). Research by Harry Harlow, a former President of the American Psychological Association, demonstrated that rhesus monkeys deprived of their mother's love developed behaviors similar to infantile autism, highlighting the importance of affectional needs (Barnett, 2017).

2.20 The Concept of Gender and Performance in Education

The concept of gender within the teaching and learning process has garnered considerable attention from psychologists, biologists, and educational researchers, leading to a substantial body of literature on its various dimensions (Bichi, 2002). The third research question of this study specifically addresses the academic achievement of male and female students in the topic of Control and Coordination, necessitating a review of pertinent literature on gender and academic achievement in science education. A significant volume of research has been dedicated to examining gender differences in school learning (Nsofor, 2010), with studies indicating that males often demonstrate more positive attitudes toward science than females (Prokop, Tuncer, & Chuda, 2007). Furthermore, an analysis of statistical contributions to Science, Technology, Mathematics, and Engineering (STME) in Africa, particularly in Ghana, reveals a notably low rate of participation by women (Olagunji & Abiona, 2008), a trend supported by evidence from science and technology-based organizations across the region.

Research findings on gender disparities in instructional outcomes present a complex picture. Several studies have identified differences in achievement and instructional method efficacy that favor male students (Bichi, 2002; Usman, 2007; Olagunji & Abiona, 2008; Olorukoorba, Lawal, & Jiya, 2012; Obeka, 2013). In contrast, other

studies have reported no significant gender-based differences in academic achievement (Maikano, 2007; Usman, 2010). The application of instructional treatments to mixed-gender populations has been shown to improve overall achievement, though often with differing outcomes for each gender (Patrick & Ezenwa, 2000).

Specific findings illustrate this inconsistency. Salami (2013) reported higher mathematics performance among males, while Usman (2007) found that male Biology students outperformed females in rigorous tasks. Similarly, Obeka (2009) identified gender as a significant factor in environmental education, with males achieving higher scores. Contrary to these findings, Mari (1994) and Bichi (2008) found that female students outperformed males in integrated science and biology, respectively. A number of studies, including those by Ezeudu and Obi (2013) in chemistry, Maikano (2007) in ecological concepts, and Umoh (2003), found no significant performance difference between genders, particularly when entry qualifications were equivalent. Usman (2010) suggested that methods like the outdoor laboratory can enhance achievement irrespective of gender.

Scholars have proposed various explanations for these disparities. Usman (2000) attributed differences to classroom teaching methods, while the American Psychological Association (2010) highlighted the role of social and cultural factors in shaping perceived or actual performance gaps. Importantly, studies by Kajuru and Ado (2012) and Obeka (2013) demonstrate that innovative, resource-rich teaching strategies can enhance academic achievement for all students, regardless of gender. Obeka's (2013) quasi-experimental study in particular found that using integrated instructional materials significantly boosted achievement and fostered practical collaboration among students.

Within this study, academic achievement and gender are examined as key variables to determine whether an animation-based instructional strategy influences performance in a way that perpetuates or mitigates existing gender stereotypes.



CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter discusses the methodology used for the study. Among the issues discussed here include the research approach, area of study, research design, the population of the study, the sample and sampling procedure, research instrument, data collection procedure, data analysis and ethical considerations.

3.1 Research Approach

Yates (2004) identifies the three predominant research approaches as quantitative, qualitative, and mixed methods, with the latter integrating elements of both. The selection of an appropriate approach is contingent upon the specific research problem and objectives. For this investigation, a quantitative approach was adopted. This methodology is concerned with determining the relationship between dependent and independent variables through statistical models and formulas (Creswell & Creswell, 2017).

This approach is valued for its capacity to ensure accuracy, reliability, and the generalizability of findings by developing testable hypotheses and theories, thereby fostering greater objectivity (Saunders, Lewis, & Thornhill, 2012). A key advantage of quantitative research is its objective nature, wherein the researcher's influence on the outcomes is minimized, in contrast to more interpretative qualitative methods (Creswell & Creswell, 2017). Data is external to the researcher, and results are derived from statistical analysis rather than subjective interpretation.

Consequently, the quantitative approach was deemed most suitable for this study's aim of investigating the relationship between the independent variables—specifically,

computer-based animation and traditional lecture-based instructional methods—and the dependent variables of student performance and attitude. Its application was essential for determining whether a statistically significant relationship exists, particularly regarding the effect of computer-based animation on teaching and learning the topic of Control and Coordination in Biology.

The decision to employ computer-based animation as the primary instructional strategy was driven by the abstract nature of the topic. Key focal areas, such as the plan of the nervous system, the structure and function of the brain and spinal cord, the transmission of impulses, and the mechanics of the eye, are conceptually challenging for students to visualize through traditional lecture methods alone.

Animations provide dynamic visualizations that illustrate processes unfolding over time, such as nerve impulse propagation. This aligns with Mayer's (2009) cognitive theory of multimedia learning, which posits that learners understand complex information more effectively when words are paired with visual representations. This approach engages both the verbal and visual channels of working memory, reducing cognitive load. Similarly, Paivio's (1991) dual coding theory supports this idea, suggesting that presenting information in both verbal and pictorial forms enhances comprehension and retention.

The computer-based animation designed for this study addressed each focal area. For the general plan of the nervous system, animations illustrated the distinction between the central and peripheral nervous systems and their interactions. For the brain and spinal cord, three-dimensional animations demonstrated structural organization and the protective meninges. The protection of the nervous system was visualized through layered representations of the skull, cerebrospinal fluid, and meninges. The

transmission of impulses was animated by showing the propagation of electrical signals along neurons and the role of neurotransmitters at synapses, thereby making visible what is otherwise invisible. Finally, the eye was explained using an animation showing the path of light, refraction through the cornea and lens, and the role of photoreceptors in image formation.

The choice of animation as an instructional medium is further supported by research indicating that graphical representations have limited expressive power compared to text, but this very restriction reduces abstraction and facilitates more efficient inference-making (Stenning & Oberlander, 1995). Moreover, Ainsworth (2008) emphasizes that animations influence learning at multiple levels including perceptual, cognitive, affective/motivational, strategic, and rhetorical making them well-suited for teaching biology concepts that require both conceptual understanding and sustained engagement.

Students were introduced to a storyboard animation group project summarizing the sequence of processes in impulse transmission and sensory coordination, this hands-on-interactive interface encouraged learners to reconstruct the flow of event thereby preparing them to engage and link lessons to real life

Thus, the use of computer-based animation in this study was intended to make abstract biological processes more concrete, to enhance conceptual understanding, and to support retention of knowledge among Senior High School students.

3.2 Area of the Study

The Zion College in Anloga is a mixed public Senior High School located along the Keta-Anyanui Road in the Volta Region of Ghana, within the Anloga District. Geographically, it is situated north of the Atlantic Ocean, northeast of Anloga Clinic, south of the Keta Lagoon, west of the Volta River, and east of the Ghana-Togo

boundary. The Atsiehepe Community, where the school is located, is the second largest in the Anloga District, sharing boundaries with Whuti, Lashibi, and Low-Cost communities. The community covers an area of 90,624.9 acres, including 36,855.4 acres of lagoon and Volta River, 18,189.86 acres of wetland, and 34,801.1 acres of arable land. According to the 2022 Housing Census, the Municipality has an estimated population of 94,895, with 26,868 houses and 25,751 households. Using the Volta Region's growth rate of 2.5%, the population of Atsiehepe is projected to be 16,987 as of 2022 (GSS, 2022). The community is predominantly farming and fishing, with its inhabitants mainly engaged in these activities. The Zion College, with a population of approximately 2,100 students and 101 teachers, is one of the fastest-growing public schools in Ghana. The school has four houses: Sri, Akpalu, Kotoka, and Nkrumah. The study area was selected for its comprehensive infrastructure, which includes consistent electrical power, conducive classroom environments, and adequate personnel, thereby establishing an ideal setting for the implementation of this research. Furthermore, the researcher's pre-existing familiarity with the area and its institutional context served to facilitate efficient and effective data collection procedures. The study aimed to address students' difficulties in understanding abstract science concepts, such as control and coordination.

3.3 Research Design

This study employed a quasi-experimental pretest-posttest-delayed posttest two-group design. As noted by Nworgu (2006), quasi-experimental research designs are used when randomization of research subjects is not feasible. In this study, random sampling and assignment of subjects to groups were not possible, necessitating the use of this design. The experimental group (X) received instruction on control and coordination concepts using computer-based animation, while the control group (Y) received

instruction on the same concepts using traditional lecture-based methods. The design of the study was as follows:

Experimental group (X):	O1	X1	O2	O3
				
Control group (Y):	O4	X2	O5	O6

Where O1, O4 = pre-test (performance to the two groups)

O2, O5 = post-test (performance to the two groups)

O3, O6 = delayed post-test (retention rate performance to the two groups)

X1 = treatment is given through computer-based animation instructional method.

X2 = traditional lecture-based instructional method of teaching

The choice of the design to avoid ethical issues such as interrupting classes or reorganizing students into new groups which could affect their learning.

Some of the advantages of using the design includes the following:

- i. Allows greater external validity as it aligns with real practical applications, therefore more generalizable.
- ii. Because there is no randomization, the independent variable is more controlled and targeted.
- iii. The researcher is able to freely choose his special areas and also the design involve less expenditure.

While certain weaknesses such as potential biases exist, this can serve as focal point for future research. Nonetheless, the quasi-experimental design provides strong evidence of a causal relationship between the independent and dependent variables despite the absence of randomization. In this study, administering a pretest helped ensure that the student were at a similar baseline level thereby minimizing anticipated biases and strengthening the validity of the interventions impact on student performance

3.4 Population of the Study

A research population is defined as a well-defined, complete collection of individuals or objects that share a common set of characteristics or traits. For this study, the target population comprised all Biology students across Senior High Schools in the Anloga District (N = 350) in the Volta Region of Ghana. The accessible population, however, was delineated as the Form Two Biology students at Zion College Senior High School within the same district, totaling one hundred and seventeen (117) students.

The selection of this topic and population was informed by several critical factors, primarily concerning persistent challenges in student performance. An analysis of reports from the West African Examinations Council (WAEC) spanning the June 2001-2014 WASSCE, as well as more recent assessments up to 2022, indicated that candidates consistently demonstrated significant difficulty with the concepts of the nervous and endocrine systems. Common weaknesses identified include:

- An inability to explain complex biological mechanisms, such as the reflex arc and hormonal regulation.
- Difficulty applying theoretical knowledge to real-life physiological scenarios.
- A frequent misunderstanding and misuse of essential terminology (e.g., "stimulus," "response," "homeostasis," "neurotransmitter").

- Deficiencies in drawing accurate, well-labeled biological diagrams.
- Challenges in identifying anatomical parts of the brain and nervous system and correctly associating them with their functions.
- A general weakness in articulating concepts using appropriate scientific vocabulary.

These difficulties in grasping abstract biological concepts, particularly those under "Control and Coordination," were also observed anecdotally in sampled schools.

Zion College was selected as the research site because it possesses all the necessary facilities and conditions to support this investigation. These include equipped science and ICT laboratories, consistent electricity, conducive classrooms, a library stocked with relevant Biology textbooks, and qualified personnel. Furthermore, the researcher's existing familiarity with the institution was considered a practical advantage for facilitating effective data collection.

3.5 Sample and Sampling Technique

A sample represents a subset of a statistical population that is selected for investigation, with its properties analyzed to draw inferences about the entire population (Webster, 1985). Sampling techniques encompass the methodological procedures and strategies researchers employ to select this subset during the sampling process (Castillo, 2009). In this study, 117 Year Two Biology students, comprising 36 General Science students and 81 Home Economics students, were purposively sampled and regrouped into two equivalent groups (control and experimental groups) based on their pre-intervention test scores. These groups were generated by categorizing the best scores as the traditional lecture-based instructional method (TLIM) group ($n = 60$) and the remaining students to the computer-based animation instructional method (CAIM) group ($n = 57$).

With a minimum sample size of 30 recommended by the Central Limit Theorem for experimental studies (Tuckman, 1975; Usman, 2000; Jiya, 2011), this sample was deemed viable. The best performing students were put in control group and the rest in the intervention group or the experimental group

This ensures that, the groupings minimize any academic advantage one group may have over the other subsequently questioning the internal validity of the outcome of the intervention and also the findings despite the absence of random assignment of subjects to groups

The detail of the sample is presented in the Table 1.

Table 1: Distribution of students in the Two Instructional Groups

Group	Male	Female	Total
Experimental Group	18	39	57
Control Group	17	43	60
Total	35	82	117

3.6 Data Collection Instrument

In conducting this research, two research instruments were used and these were the Control and coordination Achievement Test (CCAT) and Students Attitude Questionnaire (SAQ) on Control and Coordination (SAQCC). Control and Coordination Achievement Test (CCAT) was used to gather information on the students' performance in Control and Coordination before and after the treatment in both control and experimental groups as well as the retention rate. CCAT instrument was developed based on the control and coordination content from Senior High School Year Two Biology syllabus and some were drawn from West African Examination Council (WAEC) questions. It consists of Eight (13) multiple-choice items with four possible answers for each question (A-D), Three (3) and Nineteen (16) labelling test

(parts identification test) items and Five (5) essay type questions (Appendix A). To ensure the validity of the test items, a table of specifications, (Appendix D) which showed the various levels of learning against the control and coordination concepts was prepared. Based on the learning objectives, test items were developed in all categories.

Students Attitude Questionnaire on Control and coordination (SAQCC) was to examine the students' attitude toward the concepts of control and coordination before and after the treatment (Appendix B).



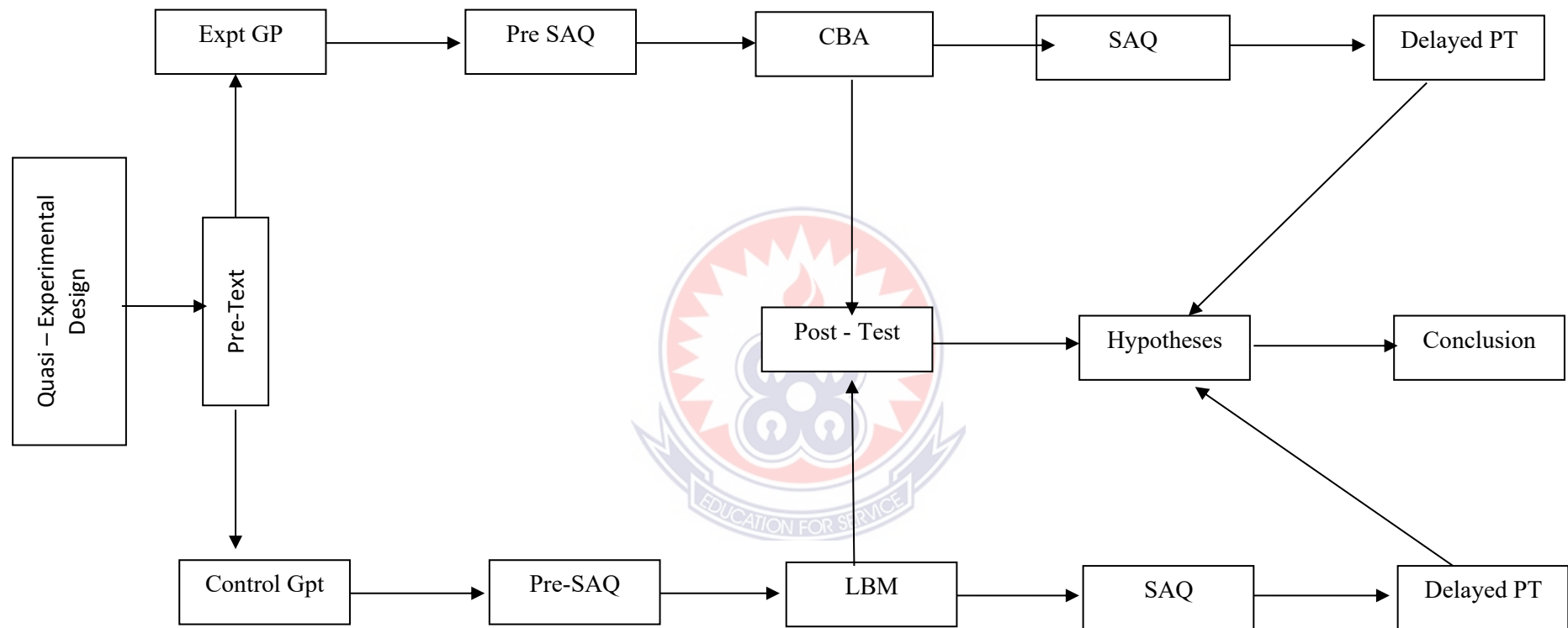


Figure 2: Methodology

3.7 Validity of Instruments

The accuracy of a study tool in measuring what it was designed to assess is termed validity (Joppe, 2000). Both the Control and Coordination Achievement Test (CCAT) and the Students' Attitude Questionnaire on Control and Coordination (SAQCC) were validated by experts in the field of study. The validity of CCAT was first ensured by comparing the demands of the questions to the demands of the Biology syllabus (Joppe, 2000). The Ghana Syllabus for SHS emphasizes the recall, comprehension and application of concepts which was adhered to by emphasizing the use of a Table of Specification. (See Appendix D) to summarize the scope of the lessons taught, Then the research instruments were validated by three experts: two from the Biology Education Department and one expert from the Measurement and Evaluation Department, University of Education, Winneba. They examined the items in terms of clarity of instruction to the respondents, proper wording of the items and appropriateness and adequacy of the items in measuring what they were supposed to measure. The validator's corrections and recommendations were used to prepare the final copy of the questionnaire and the test items. The instruments were validated once more by recording behaviours as soon as they were noticed.

3.8 Pilot Test

Year Three General Science Biology students at Anglo Senior High School were purposively and conveniently selected for the pilot testing of the instrument, the Control and Coordination Achievement Test (CCAT). This group was chosen because they had already covered all topics related to control and coordination and therefore possessed comprehensive content knowledge of the concepts. As such, their test performance provided the most appropriate data for validating and confirming the reliability of the

test items. In addition, the school shared similar characteristics with the institution selected for the main study, making it suitable for the piloting process.

The primary purpose of the pilot testing was to establish the validity and reliability of the CCAT. According to Teijlingen and Hundley (2011), administering an instrument to pilot subjects in the same way it will be used in the main study allows for valuable feedback. In this study, the pilot process enabled the researcher to identify and eliminate unnecessary, difficult, or ambiguous questions, as well as to reword or rescale items that were not answered as anticipated. Items that produced problematic scores were subsequently reviewed and refined prior to the actual data collection. Furthermore, the pilot test provided information on the time required to complete the CCAT, which allowed the researcher to determine whether the allotted time was reasonable.

3.9 Reliability of Instrument

Reliability refers to the consistency of a measurement across time, indicating whether it produces stable results on repeated trials (Christine, 2013). In this study, the Kuder-Richardson Formula 20 (KR-20) was employed to determine the reliability and internal consistency of the Control and Coordination Achievement Test (CCAT). This method is particularly suitable for instruments with dichotomously scored items those with correct and incorrect responses such as the CCAT, which comprised multiple-choice questions, true-or-false items, and fill-in-the-blank tasks. The KR-20 is also advantageous due to its relative simplicity of application.

The reliability coefficient for the CCAT was calculated as 0.91. This indicates that 91% of the variability in test scores was attributable to true differences among examinees, with only 9% resulting from measurement error. Given that this value falls within the

acceptable benchmark for reliable instruments (Leedy & Ormrod, 2005), the CCAT was deemed sufficiently reliable for use in data collection for the study.

3.10 Data Collection Procedure

Formal authorization to conduct the study was secured through an introductory letter from the Department of Biology Education, which was presented to the authorities of the selected school. Prior to data collection, informed consent was obtained from all participants to guarantee voluntary involvement. Respondents were assured of the confidentiality and anonymity of their responses and were informed that the collected data would be represented accurately without any form of manipulation to influence the findings.

Following approval from the school administration, a pre-intervention test (pre-test) on the topic of control and coordination was administered to all 117 sampled students. The results of this pre-test were utilized to stratify the cohort into two performance-based equivalent groups: an experimental group and a control group.

The control group received instruction on control and coordination concepts via a traditional lecture-based method over a two-week period. This approach emphasized teacher-led lectures, interactive discussions, the use of textbooks, still images, and charts. Crucially, the pedagogical delivery for this group deliberately excluded the use of any form of animation or digital simulation (see Appendix E).

Concurrently, the experimental group was taught the same concepts using a computer-based animation instructional method. This treatment integrated the lecture approach with supplemental animations, specifically incorporating a curated video sourced from <https://youtu.be/Y7vcE2eaeeg> into the lesson plan.

At the conclusion of the two-week instructional period, both groups were assessed using a post-test, designated as the post-CCAT (Appendix A), to measure academic performance. To evaluate the retention of learned concepts, a delayed post-test (post post-CCAT) was administered three weeks after the initial post-test. The quantitative data derived from these test scores were subsequently analyzed to address the research questions and test the stated hypotheses.

This study employed a quasi-experimental design, specifically a pretest-posttest control group design with an additional delayed posttest. As delineated in Figure 2, the research procedure commenced with the administration of a pretest to establish a baseline of participants' knowledge of Control and Coordination. Simultaneously, a Student Attitude Questionnaire (SAQ) was administered to gauge learners' initial perceptions and attitudes toward biology as a subject.

Based on the pretest outcomes, students were assigned into experimental and control groups to ensure comparability. The experimental group was taught with computer-based animation, while the control group received instruction through conventional methods.

After the instructional phase, a posttest was administered to both groups to measure immediate learning outcomes. At the same time, a second administration of the SAQ was conducted to identify any changes in student attitudes toward the subject.

Subsequently, appropriate statistical analyses were applied. A paired samples t-test was used to compare pretest and posttest scores within each group, while an independent samples t-test was used to compare performance between the experimental and control

groups at given stages. The same tests were employed for SAQ responses to determine both within-group and between-group attitudinal changes.

Finally, a delayed posttest was administered three weeks later to both groups to examine the retention of knowledge and persistence of attitudinal change. This provided data to assess not only the immediate effect of the intervention but also its longer-term impact.

3.11 Data Processing and Analysis

The data were analyzed using a quantitative approach based on the research questions formulated for this study (Cooper & Schindler, 2006). Quantitative research focuses on precise measurement and determines facts and figures (Cooper & Schindler, 2006).

The data obtained from this study were subjected to analysis using both descriptive and inferential statistical methods, facilitated by the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including means and standard deviations, were employed to summarize the data, while inferential statistics, comprising paired and independent samples t-tests, were used to draw conclusions about the population based on the sample data.

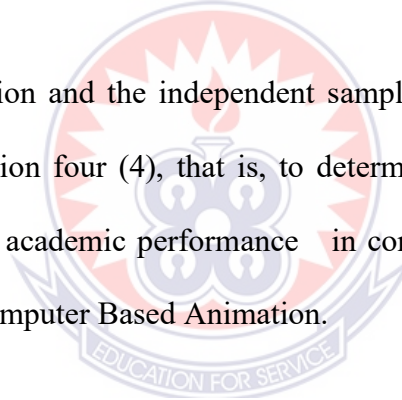
To address research question one, which examined the effect of computer-based animation on the teaching and learning of control and coordination concepts in Biology, the post-test (post-CCAT) scores of the experimental and control groups were analyzed. This analysis utilized means, standard deviations, independent samples t-tests, Cohen's d effect size measurements, and box plots to compare the performance between the two instructional groups.

For research question two, which aimed to assess the improvement in students' attitudes toward control and coordination concepts through computer-based animation, the

scores from the pre-Student Attitude Questionnaire (pre-SAQ) and post-Student Attitude Questionnaire (post-SAQ) were compared. Means, standard deviations, paired samples t-tests, and bar charts were used to evaluate changes in attitude within and between groups.

Research question three sought to determine the extent to which computer-based animation enhanced long-term retention of the concepts. The post-test and delayed post-test scores of both the experimental and control groups were analyzed using means, standard deviations, Cohen's d effect size, paired samples t-tests, independent samples t-tests, and box plots. This comprehensive analysis allowed for a robust evaluation of retention outcomes attributable to the instructional method.

Mean, standard deviation and the independent samples t-test statistics were used to analyze research question four (4), that is, to determine whether there were gender difference in students' academic performance in control and coordination concepts when taught using Computer Based Animation.



CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents and discusses the main results of the study. This study investigates the learning outcomes with computer-based animation in the teaching and learning of "Control and Coordination" of second-year Biology students among Zion College students in the Volta Region of Ghana. Two second year Biology classes totaling one hundred and seventeen (117) were sampled and regrouped into two study groups for the study. The data analysis for this study employed both descriptive statistics, including means and standard deviations, and inferential statistics, comprising paired and independent samples t-tests, Cohen's d effect size measurements, and box plots. These analyses were conducted using the Statistical Package for the Social Sciences (SPSS), version 26. The results are presented and interpreted in direct response to the study's four research questions. This section forms the essential foundation for the conclusions drawn, articulating the principal findings and underscoring the study's contribution to the existing body of knowledge.

4.1 Results of the Study

This section presents the main findings of the study in relation to the research questions posed. Both descriptive and inferential statistics were employed in the analysis, with the support of the Statistical Package for the Social Sciences (SPSS).

Analysis of Homogeneity of the Study Groups' Knowledge of the Concept of Control and Coordination Prior to the Intervention

To ascertain whether the two study groups were equivalent in terms of their prior knowledge of the concept of control and coordination, their pre-test scores (pre-CCAT)

were subjected to an Independent Samples *t*-test. The results of this analysis are presented in Table 2.

Table 2: Independent Sample *t*-Test Analysis of Homogeneity of the study groups

Knowledge in Coordination and Control Concept prior to the Study

Study Groups	Independent Samples <i>t</i> -Test						
	N	Mean	SD	<i>df</i>	<i>t</i> -cal	<i>p</i> -value	ES (Cohen <i>d</i>)
Control Group (Traditional Lecture-Based)	60	16.83	3.98	115	.530	.597	.026
Experimental Group (Computer-Based Animation)	57	16.42	4.44				

Source: Field Data 2023

Significance level, $\alpha = 0.05$, SD = Standard

Deviation, ES = Effect Size

Table 2 reveals that there was no statistically significant difference in pre-CCAT scores between the sampled students from the two groups ($t = .530, p > .05$). That is, prior to the study the two study groups (control group and experimental group) were at the same level in terms of their knowledge in the concept of control and coordination and therefore appropriate for the study.

4.1.1 Research Question 1: What is the effect of computer-based animation on the teaching and learning of Control and coordination concept?

To examine the effect of computer-based animation on the teaching and learning of the concepts of control and coordination, the post-test scores (post-CCAT) of the experimental and control groups were analyzed using the mean, standard deviation, Cohen's *d* effect size, and Independent Samples *t*-test (Table 2). In addition, a box plot (Figure 2) was used to provide a pictorial representation of the performance of students

in both groups, which further aided in judging the practical significance of the test scores.

Table 3: Comparing student achievement using computer-based animation and traditional teaching approaches based on Post-CCAT Scores [Independent samples *t*-test]

Cognitive Level	Max. Mark	Instructional Method	No.	Mean	SD	<i>df</i>	<i>t</i>	<i>p</i>	ES (Cohen <i>d</i>)
Knowledge	10	Traditional Lecture-based	60	8.95	0.99	115	1.14	.10	0.07
		Computer-based Animation	57	8.73	0.91				
Comprehension	11	Traditional Lecture-based	60	9.62	0.84	115	0.73	.004	0.28
		Computer-based Animation	57	11.29	0.88				
Application	9	Traditional Lecture-based	60	6.45	1.44	115	2.02	<.001	0.36
		Computer-based Animation	57	8.07	0.98				
Overall Test	30	Traditional Lecture-base	60	25.53	1.95	115	4.22	<.001	0.31
		Computer-based Animation	57	27.09	2.03				

Source: Field Data 2023

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

The results in Table 3 showed no significant difference in mean post-CCAT scores between the experimental and control groups for overall cognitive-level questions ($t = 1.14$, $p = .10 > .05$). However, significant differences were found in two specific cognitive domains: comprehension ($t = .73$, $p = .004$, $ES = 0.28$) and application ($t = 2.02$, $p < .001$, $ES = 0.36$). In both cases, the experimental group taught with computer-based animation outperformed the control group taught through traditional lecture-based methods. The calculated Cohen's *d* values indicated moderate to large effect sizes, suggesting that computer-based animation had a positive and practical impact on students' comprehension and application of the concepts.

Furthermore, a significant difference was observed in the overall post-CCAT total score ($t = 4.22$, $p < .001$) in favor of the experimental group, with a large effect size (Cohen's $d = 0.31$). This higher mean performance demonstrates that students taught with computer-based animation achieved greater mastery of the control and coordination concepts compared to those taught with lecture-based instruction. Figure 3 provides a visual comparison of the post-test performance between the two groups.

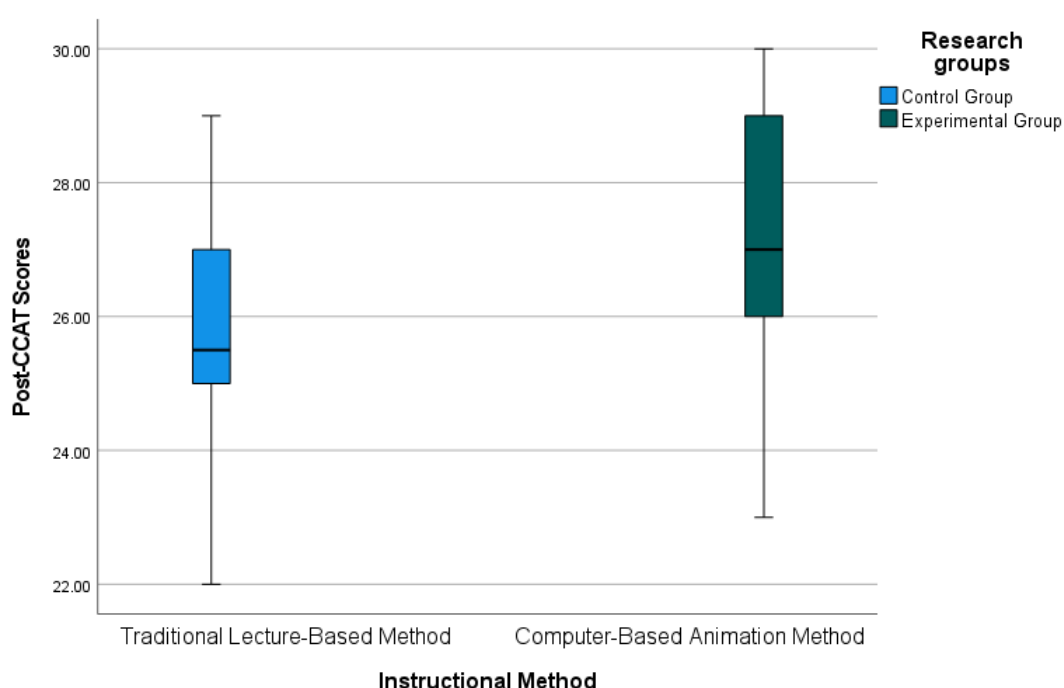


Figure 3: Comparing the Performance of Students Taught with Computer-based Animation and Traditional Lecture-based Instructional Methods Using Post- CCAT Scores

Figure 1 illustrates that students taught with the computer-based animation method outperformed those taught with the traditional lecture-based method in their understanding of the control and coordination concept. The box plot shows that the experimental group achieved higher minimum and maximum post-test (post-CCAT) scores (23 and 30, respectively) compared to the control group (22 and 29,

respectively). Similarly, the median score for the computer-based animation group was 27, exceeding the control group's median of 25.5. These results suggest that the effective use of computer-based animation can enhance students' cognitive performance more than traditional lecture-based instruction, particularly in comprehension and application-level questions.

4.1.2 Research Question 2: To What Extent Does the Use of Computer-based Animation Instructional Method Improve Students' Attitude toward Control and coordination Concepts?

To answer the research question two, that is the extent to which the use of computer-based animation instructional method improves students' attitude toward control and coordination concept, paired sample *t*-test and bar chart were used to analyze the mean scores of pre-SAQCC and post-SAQCC in each of the two instructional groups (see Table 4).

Table 4: The Extent to which the Use of Computer-based Animation Instructional Method Improve Students' Attitude toward Control and coordination

Group	No.	Pre-SAQCC		Post-SAQCC		Mean Diff.	<i>t</i> -cal	<i>p</i> -value
		Mean	S.D	Mean	S.D			
Experimental Group (Computer-based)	57	29.5	3.23	48.8	2.56	19.3	3.23	<.001
Control Group (Traditional-based)	60	30.2	2.12	34.2	3.97	4.0	2.69	0.19

Source: Field Data 2023

Significant at 0.05

From the Table 4, it is indicated that students in the experimental group showed a very positive and significant increase in their attitude toward control and coordination concept after been exposed to the computer-based animation instructional method ($t =$

3.23, $p = <.001$) compared to their counterparts (control group) who were taught with traditional lecture-based instructional method ($t = 2.69$, $p = 0.19$).

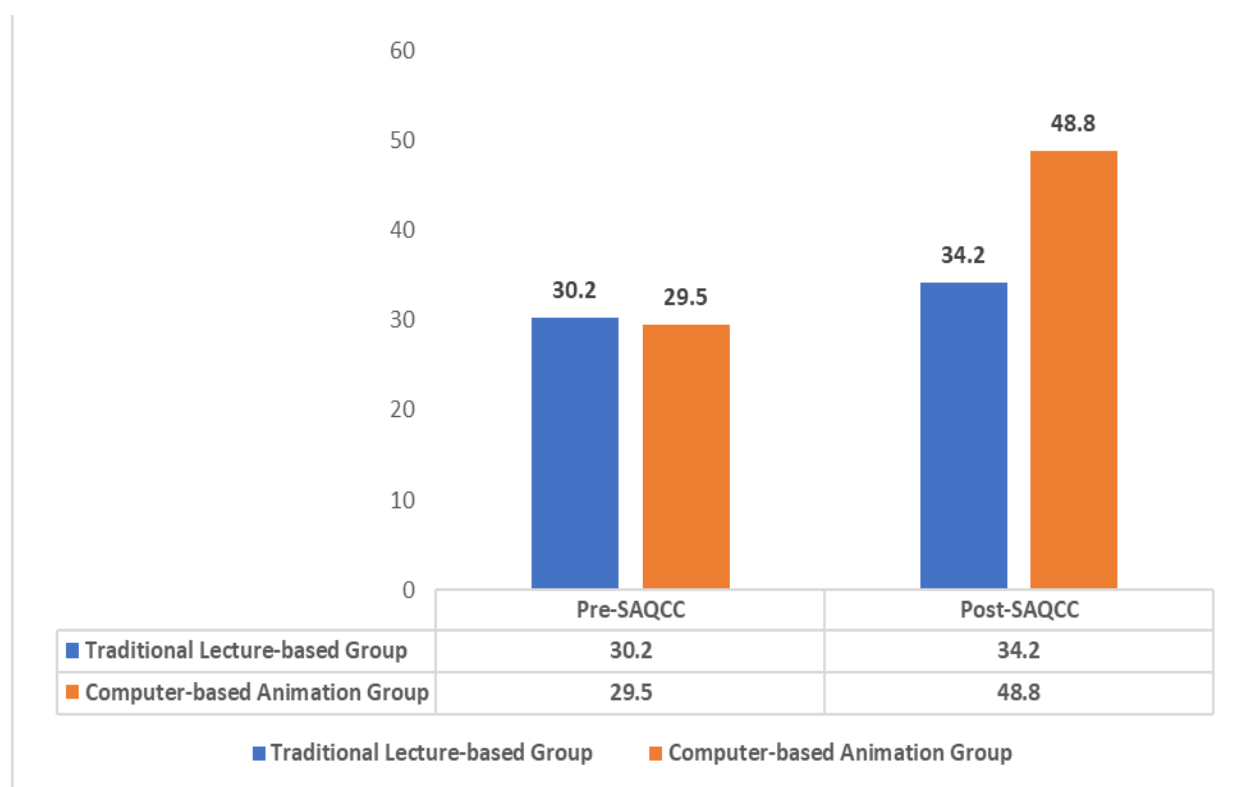


Figure 4: Bar Chart Illustration of Students Attitude towards Coordination and Control Before and After the Interventions

Figure 2 provides visual evidence of the positive impact of computer-based animation on students' attitudes toward control and coordination concepts in Biology. The experimental group recorded mean scores of 29.5 (pre-intervention) and 48.8 (post-intervention) on the Students' Attitude Questionnaire on Control and Coordination (SAQCC), reflecting a substantial mean increase of 19.3. In contrast, the control group obtained mean scores of 30.2 and 34.2 before and after the intervention, with a modest mean difference of 4.0. These findings indicate that students in the experimental group demonstrated a more positive attitudinal change toward control and coordination concepts when taught with computer-based animation compared to their peers taught

with the traditional lecture-based method. This suggests that computer-based animation had a significant positive effect on students' attitudes toward the concepts.

4.1.3 Research Question 3: To what extent does the use of computer-based animation enhance long-term retention in the teaching and learning of control and coordination?

To evaluate the long-term retention of control and coordination concepts facilitated by computer-based animation, a comprehensive statistical analysis was conducted using post-test and delayed post-test scores from both the experimental and control groups. The analysis incorporated descriptive statistics (mean and standard deviation) to summarize score distributions, while inferential methods—including paired samples t-tests, independent samples t-tests, and Cohen's d effect size—were employed to compare performance within and between groups over time. These results are detailed in Tables 5 and 6.

Additionally, a box plot (Figure 3) provided a visual representation of delayed post-CCAT score distributions for both groups, aiding in the interpretation of practical significance and variability in retention outcomes. This combination of analytical approaches allowed for a robust assessment of the sustained impact of computer-based animation on student learning.

Table 5: Mean Decline Analysis and Paired Samples t-test Results for Post-CCAT and Delayed post-CCAT Scores within 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)
Traditional Lecture-based (Control Group)	25.53	22.22	3.31	2.85	59	6.06	<.001	0.26
Computer-based Animation (Experimental Group)	27.09	26.46	0.63	3.45	56	9.53	.09	0.07

Source: Field Data 2023

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

$\bar{x}_p$ = Mean score of the post-CCAT, $\bar{x}_d$ = Mean score of the delayed post-CCAT

The data presented in Table 5 enables an examination of the extent to which students' mean scores declined from the post-test to the delayed post-test within each instructional group.

As shown in the table, students taught using the traditional lecture-based method exhibited a statistically significant mean score decline of 3.31 points, representing a large effect size ($t = 6.06$, $p < .001$, Cohen's $d = 0.2$). This decline is evident when comparing their post-CCAT scores ($\bar{x} = 25.53$) with their delayed post-CCAT scores ($\bar{x} = 22.22$).

In contrast, students taught using the animation-based instructional method showed no statistically significant decline in scores ($t = 9.531$, $p = 0.09$, Cohen's $d = 0.07$), with only a minimal mean reduction of 0.63 points between their post-CCAT ($\bar{x} = 27.09$) and delayed post-CCAT scores ($\bar{x} = 26.46$).

Furthermore, a substantial mean difference of 4.24 points was observed in the delayed post-CCAT scores between the computer-based animation group and the traditional lecture-based group, favoring the animation-based approach. To determine whether this difference was statistically significant, an independent samples t-test was conducted on the retention test (delayed post-CCAT) scores, the results of which are presented in Table 6. This analysis serves to evaluate the comparative effectiveness of the two instructional methods on students' retention of the material.

Table 6: Examining the Long-term Retention of the Concept between Students Taught with Computer-based Animation and Traditional Lecture-based Methods using their Retention-test Scores (Delayed- CCAT)

Independent Samples t-Test							
Study Groups	N	Mean	SD	df	t-cal	p-value	ES (Cohen d)
Control Group (Traditional Lecture-Based)	60	22.32	2.69	115	9.24	<.001	.27
Experimental Group (Computer-Based Animation)	57	26.46	2.09				

Source: Field Data 2023

Significance level, $\alpha = 0.05$, SD = Standard

Deviation, ES = Effect Size

Based on the statistical analysis presented in Table 6, it can be concluded that a statistically significant difference exists in the mean retention scores between students taught using computer-based animation and those taught through traditional lecture-based methods, with the computer-based animation group demonstrating superior retention ($t = 9.24$, $p < .001$).

The effect size, measured by Cohen's d ($d = 0.27$), indicates a large practical significance in the difference between the two instructional approaches, according to Cohen's (1988) benchmarks. This suggests that the use of computer-based animation not only enhances short-term learning but also substantially improves long-term retention of control and coordination concepts in biology compared to traditional lecture-based instruction.

These findings underscore the pedagogical value of integrating animation-based tools in science education, particularly for complex and abstract biological processes.

Moreover, the box plot illustrations in Figure 5 confirm the extent to which students taught with animation-based instructional method outperformed their counterparts taught with the traditional lecture-based instructional method in terms of retention rate of control and coordination concepts.



Figure 5: Comparing the Retention Performance of Students Taught with Computer based Animation and Traditional Lecture-based Instructional Methods Using Delayed-CCAT Scores

Figure 3 shows that students taught with the animation-based instructional method outperformed those taught with the traditional lecture-based method in terms of retention of control and coordination concepts. The box plot indicates that the minimum retention score (delayed post-CCAT) for the animation-based group was 20, compared to 17 for the traditional lecture group. Similarly, the median retention score for the animation-based group was 26, higher than the 23 recorded by the lecture-based group. The maximum retention score was also higher in the animation-based group (30) than in the lecture-based group (28). These results suggest that students taught through

animation-based instruction demonstrated stronger retention of knowledge than those taught with traditional methods. Thus, the effective use of animation-based instructional strategies can enhance students' long-term retention of control and coordination concepts in Biology.

4.1.4 Research Question 4: What is the effect of Computer-based animation method on the gender of students' academic performance in control and coordination concepts?

Data from research question four (4) were analysed using means, standard deviations and the independent samples t-test statistics and the result is shown in the Table 7 below.

Table 7: Effect of Computer-based Animation Method and Gender Differences on Students' Academic Performance in Control and coordination Concepts

Independent Samples t-Test							
Gender	N	Mean	SD	df	t-cal	p-value	ES (Cohen d)
Male	19	26.17	2.24	55	.49	.251	0.21
Female	38	25.44	2.31				

Source: Field Data 2023

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

Table 7 indicates that computer-based animation had no significant interaction with gender in influencing students' academic performance in the teaching and learning of control and coordination concepts. The effect of computer-based animation on gender differences was not statistically significant, as shown by the $p\text{-value} > .05$ [$t = .49$, $p = .251$]. This suggests that the effectiveness of the computer-based instructional method is not dependent on gender and that gender does not influence learning outcomes when this method is applied. Therefore, the computer-based instructional method can be

considered gender-friendly, as it enables both male and female students to learn effectively through this approach.

4.2 Discussion of the Results

This section presents the discussion of the study's findings in relation to its purpose, which was to investigate the learning outcomes of computer-based animation in the teaching and learning of Control and Coordination concepts among second-year Biology students at Zion College in the Volta Region of Ghana. The discussion is guided by the study's findings, the research objectives and questions, as well as relevant assertions from the reviewed literature.

4.2.1 Effect of Computer-based Animation on the Teaching and Learning of Coordination and Control Concepts

The findings of the study revealed that students taught using the computer-based animation instructional method outperformed their counterparts who were taught through the traditional lecture-based approach in the teaching and learning of control and coordination concepts. This outcome may be attributed to the use of instructional movies, animations, and pictures, which enabled learners to engage multiple senses rather than relying solely on auditory input. The visual representation of control and coordination concepts reduced abstraction and thereby enhanced students' understanding (Aiyedun, 2020; Ameyaw & Kyere, 2019; Ayotola & Abiodun, 2010; Kyere, 2018; Oladejo et al., 2023; Rotbain et al., 2008; Stith, 2004; Tayo, 2012; Thomas & Israel, 2014). Supporting this, Ameyaw and Kyere (2019) reported that animation-based teaching approaches improved students' academic performance more effectively than traditional lecture-based methods. Similarly, Oladejo et al. (2023) found a statistically significant main effect of computer simulation instructional strategies on

student performance. In the same vein, Tayo (2012) showed that students taught with animated agricultural packages achieved higher scores than those taught through conventional lecture methods. Rotbain et al. (2008) also demonstrated that students instructed with computer animations significantly outperformed their peers in the control group on measures of content knowledge. Likewise, Thomas and Israel (2014) observed notable differences in academic achievement between students exposed to animation-based instructional methods and those taught with traditional lectures.

4.2.2 The Extent to which the Use of Computer-based Animation Instructional Method Improve Students' Attitude toward Control and coordination Concepts

The study result revealed that students in the experimental group showed a very positive and significant increase in their attitude toward control and coordination concept after been exposed to the computer-based animation instructional method ($t = 3.23$, $p = <.001$) compared to their counterparts (control group) who were taught with traditional lecture-based instructional method ($t = 2.69$, $p = 0.19$).

The experimental group's significant improvement in attitude towards control and coordination concepts can be attributed to the interactive nature of computer-based animation instructional methods, which enable students to actively participate in the learning process and convert abstract knowledge into concrete understanding, thereby sparking interest and positive attitudes (Aiyedun, 2020; Berger et al., 1994; Ercan, 2014; Aden, 1995). This finding aligns with previous research demonstrating that computer-based instruction (animation-based instructional approach) significantly

enhances students' attitudes and academic achievements (Berger et al., 1994; Ercan, 2014; Aden, 1995).

4.2.3 Extent to which Computer-based Animation Method Enhance Long-term Retention Rate in the Teaching and Learning of Control and coordination

The results of the study indicated that students taught using the traditional lecture-based instructional method experienced a statistically significant mean decline between their post-CCAT and delayed post-CCAT scores. Conversely, students instructed through the animation-based method did not exhibit any significant decline between the post-CCAT and delayed post-CCAT scores. Furthermore, a statistically significant difference was found in the mean retention scores (delayed post-CCAT) between the two groups, favoring the computer-based animation group ($t = 9.24$, $p < .001$, Cohen $d = 0.13$). This finding suggests that students taught with the computer-based instructional method significantly outperformed those taught with the traditional lecture-based method on the retention test.

This outcome may be attributed to the participatory and interactive nature of computer-based animation (Aiyedun, 2020; Aksoy, 2012; Ameyaw & Kyere, 2019; Kyere, 2018). The integration of multiple videos, animations, and simulations (see Appendix D) provided learners with opportunities to construct more scientific and meaningful understandings of the concepts, thereby enhancing memory retention. As a result, students demonstrated higher retention of control and coordination concepts (Aiyedun, 2020; Ameyaw & Kyere, 2019). Supporting this, Ameyaw and Kyere (2019) reported that students taught with animation-based instruction significantly outperformed those taught with traditional lecture-based methods in both performance and retention measures. Similarly, Aksoy (2012) found that incorporating animation into the teaching

of scientific concepts improved students' retention abilities. Their findings suggest that animation-based instruction enhances recall by fostering associations, connections, and systematic thinking during memory tasks (Aksoy, 2012; Ameyaw & Kyere, 2019).

4.2.4 Effect of Computer-based Animation Method and Gender on Students' Academic Performance in Control and coordination Concepts

The study result in Table 6 revealed that gender has no effect on the students' performance when exposed to the computer-based animation instructional method. This implied that the effectiveness of the treatment (computer-based animation instructional) does not depend on gender and that gender has no influence on the effectiveness of the computer-based instructional method in the teaching and learning of control and coordination concept. All students benefitted equally, regardless of gender differences (Afuwape & Olatoye, 2004; Okoruwa, 2008; Oladejo et al., 2023). This finding aligns with previous studies that reported no significant gender effect on achievement in science (Afuwape & Olatoye, 2004; Okoruwa, 2008; Oladejo et al., 2023). Gender disparities in performance may be attributed to cultural factors, ineffective instructional approaches, or gender-biased instructional materials (Aremu, 2008). Addressing these factors could encourage girls to engage more actively in science subjects and perform equally well as boys. Oladejo et al. (2023) found no significant difference in performance between male and female students when taught with computer simulation approaches, indicating that the treatment effect was not influenced by gender (Oladejo et al., 2023).

4.3 Implications of the Study Findings for Science Education

The findings of the present study provide important insights into how the teaching and learning of Biology, particularly in relation to control and coordination concepts, can

be improved at the Senior High School level. Overall, the study revealed that the computer-based animation instructional method was more effective than the traditional lecture-based approach in facilitating students' understanding, retention, and performance. These outcomes carry significant implications for science education delivery in both curriculum design and instructional practice.

Firstly, the results underscore the need for a revised and more responsive Biology curriculum that integrates computer-based animation and other ICT applications as complementary tools to face-to-face instruction. In this regard, Ghana's ICT for Education Policy should be reviewed to emphasize the urgent requirement for teachers to adopt ICT not merely as a support, but as a core instructional tool in teaching and learning.

Secondly, effective science teaching requires the adoption of instructional approaches that are innovative, interactive, and student-centered. As such, Biology teachers play a critical role in incorporating computer-based instructional methods into their classroom practice, particularly when dealing with abstract and complex concepts such as control and coordination. Beyond improving performance, this approach has the potential to stimulate students' curiosity, interest, motivation, and imagination, ultimately leading to greater retention and long-term learning.

Finally, the implications extend to educational policy and practice at the national level. It is imperative that the Ministry of Education formally integrates computer-based animation methods into the school curriculum and creates structures to support their effective implementation. Encouraging and institutionalizing the use of this instructional method will not only enhance students' achievement but also promote lasting interest and engagement in science education.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

5.0 Overview

This chapter provides an overall summary of the study. It highlights the major findings that emerged from the collected data, from which conclusions are drawn. Based on these conclusions, recommendations are presented. In addition, suggestions for future research are outlined.

5.1 Summary of the Study

The purpose of the study was to see how successful computer-based animation may be in teaching and learning of Control and coordination concepts in Biology. This featured PowerPoint presentations as well as video and courseware components. This study was conducted using an experimental research design with a quasi-experimental design. The target population for the study was all the elective Biology senior high school students in the Anloga District in the Volta Region of Ghana (N= 850), while the accessible population was all the elective Biology students in the Zion College. In all a total of 117 elective Biology students were sampled for this study, and they were split into two groups (experimental group and control group). The experimental group was taught control and coordination through a computer-based animation method, while the control group was taught same control and coordination through a traditional lecture-based method. A pre-test and post-test accomplishment exam with a total of 30 items was employed in this study.

5.2 Summary of the Major Findings

Before examining the effects of the intervention, it was important to establish whether the experimental and control groups were comparable at the start of the study. An independent-samples *t*-test showed that there was no statistically significant difference in the pre-CCAT scores between the two groups, $t(df) = 0.530$, $p > .05$. This finding indicates that the groups began the study at almost the same entry point in terms of their knowledge of control and coordination concepts, thereby providing a fair basis for comparing the impact of the instructional approaches used.

1. The study revealed that students in the experimental group showed a very positive and significant increase in their attitude toward control and coordination concepts after been exposed to the computer-based animation instructional ($t = 3.23$, $p = <.001$) compared to their counterparts (control group) who were taught with traditional lecture-based instructional method ($t = 2.69$, $p = 0.19$).
2. The study proved that there was a statistically significant difference in the mean retention scores of students who were taught the control and coordination concepts using computer-based instructional method and traditional lecture-based instructional method in favour of the computer-based animation group ($t = 9.24$, $p < .001$, Cohen $d = 0.13$). That is, computer-based instructional method group significantly outperformed their counterparts taught with traditional lecture-based instructional method in the retention test scores.

5.3 Conclusions

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

The study results showed no statistically significant gender differences in academic performance between male and female students when taught with the computer-based instructional method ($t = .49, p > .25$).

- Students who were taught with the computer-based animation instructional method outperformed their counterparts taught with traditional lecture-based method in the teaching and learning of control and coordination concepts.
- Students showed a very positive and significant increase in their attitude toward control and coordination concept after been exposed to the computer-based animation instructional method.
- Students who received instruction through the computer-based method performed significantly better than those taught with the traditional lecture-based method on the retention test (delayed post-CCAT scores).
- There was no statistically significant gender difference in the effectiveness of the computer-based animation method. This means that in the teaching and learning of control and coordination concepts, male and female students benefited equally, and gender did not influence the effectiveness of Computer-based Animation in acquiring Control and Coordination concept.
- There was no difference in terms of achievement between male and female students when exposed to Control and Coordination concept using multimedia-based instructional approach.

Based on the findings of this study, it can be concluded that the computer-based animation instructional approach significantly enhances the teaching and learning of

Control and Coordination concepts in biology. This method demonstrates a stronger positive impact on both students' knowledge acquisition and long-term retention compared to traditional lecture-based instruction. Furthermore, the approach shows considerable potential for improving academic achievement and fostering more positive attitudes toward complex biological topics among senior high school students. Importantly, these benefits were observed across both male and female students, indicating that the computer-based animation method supports inclusive and equitable learning without gender bias. These results advocate for the broader integration of multimedia and animation-based instructional strategies in science education to enhance engagement, comprehension, and retention of challenging subject matter..

5.4 Recommendations

To achieve the Sustainable Development Goal four (4) which relates specifically to improving teaching and learning in schools, then much effort is needed from all education stakeholders and researchers to relate these goals. It is highly essential for teachers and students to be exposed to relevant ICT tools such as computer-based animation that can support the teaching and learning of Control and Coordination concepts. Consequently, the following recommendations are proposed based on the findings:

1. Biology teachers should incorporate computer-based animation instructional strategies into the teaching and learning of Control and Coordination concepts to foster effective, active, and experiential learning.
2. Existing Science Education and Secondary School Education Policies should be revised to emphasize the need for all Biology teachers to undergo training in the use of interactive animations. Such training would promote active learning strategies where students can explore, manipulate, and engage with

visual content to strengthen their understanding of nervous system processes, while also encouraging collaboration and peer learning (e.g., group discussions using interactive tools to explain impulse transmission).

3. School partner with educational software providers or leverage open-source animation tools to reduce costs.
4. Schools partner with educational software providers or leverage open-source animation tools to reduce costs.
5. Teachers should include tasks and formative assessments that test not only recall but also application and interpretation of concepts learned through interactive multimedia.
6. Teachers should adopt a variety of instructional strategies to cater for students with diverse learning styles, thereby enhancing overall academic achievement.
7. The government should equip all Senior High Schools with adequate computers, projectors, and other ICT resources to ensure Biology teachers have easy access to computer-based animation tools and digital content for effective classroom instruction.

5.5 Suggestions for further Research

- ✓ This study should be replicated with a larger sample size by involving more schools and classes, in order to enhance generalizability and strengthen the validity of the findings.
- ✓ A study to assess the knowledge level of teachers' competencies in handling ICT tools such as computer-based animation in teaching Biology would be helpful.
- ✓ Similar studies can be replicated in other Biology topics.

- ✓ Similar studies could be replicated in other subject areas, such as Chemistry, Physics, Engineering, and Mathematics, to explore the effectiveness of computer-based animation across different disciplines.
- ✓ A study to find out the innovative practices Biology teachers use in integrating computer animation content in their teaching is recommendable.
- ✓ A study to investigate challenges and benefits when using computer-based animations in teaching Biology.



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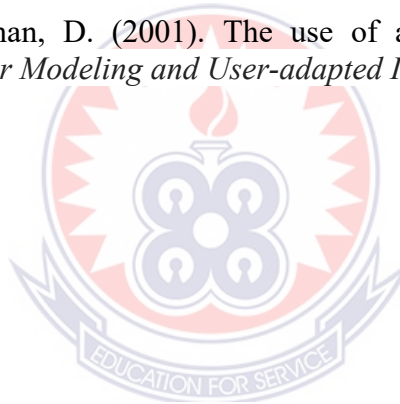
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APPENDICES

APPENDIX A

Control and Coordination Achievement Test (CCAT) for Second Year Biology

Students in the Zion College, Angola

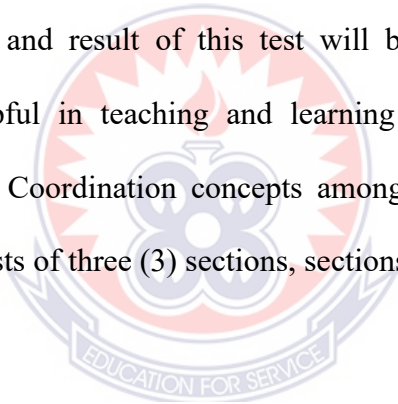
UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF SCIENCE EDUCATION

Dear Student,

This test is intended to measure your understanding, performance and retention on the topic “Control and Coordination 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 Anatomy and Physiology especially Control and Coordination 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.....

MULTIPLE CHOICES QUESTIONS / OBJECTIVE TEST

1. Which part of the brain is responsible for thinking?
 - A. cerebellum
 - B. Hypothalamu
 - C. **cerebrum**
 - D. Epithalamus
2. Which of the following is involved in temperature control in the brain
 - A. Pons and medulla oblongata
 - B. **Thalamus and epithalamus**
 - C. Somatic and sensory nervous system
 - d. Cerebellum and cerebrum
3. Which neurological cell acts as a microphage?
 - A. oligodendrocyte
 - B. Astrocyte
 - C. **microglia**
 - D. Schwann cell
4. Which lobe of the cerebrum is associated with sight?
 - A. frontal lobe
 - B. Temporal lobe
 - C. Parietal lobe
 - D. **occipital lobe**
5. Which of the following controls temperature and hunger.
 - A. Medulla oblongata
 - B. Cerebrum
 - C. **Hypothalamus**
 - D. Cerebellum
6. Which is not a function of the brain?
 - A. Thinking
 - B. **Digestion**
 - C. Memory
 - D. Balance



7. Which parts of the brain sends messages
- A. Blood vessels
 - B. Hormones
 - C. Nerves**
 - D. Bones
8. The brain is part of the
- A. respiratory system
 - B. nervous system**
 - c. endocrine
 - D. nervous
9. Which of the following explains coordination and control?
- A. how the body digest food
 - B. how the body grows and repairs itself
 - C. how different parts of the body responds to change**
 - D. How blood moves through the vessels
10. Which statement best shows an understanding of how coordination and control works in the body
- A. Muscles grow strong upon exercise
 - B. the nervous and endocrine system work together for appropriate changes**
 - C. the heart pumps blood throughout the body
 - D. lungs take in oxygen
11. Why is the peripheral nervous system important in the body?
- A. It stores information like memory
 - B. It send messages between the central nervous system to the rest of the body**
 - C. Protects the spinal cord from injury
 - D. It controls blood sugar
12. A student accidentally touches a hot object and quickly pulls the hand away which explanation is best explain how the nervous system coordinates this response?
- A. At the brain store information for future reactions
 - B. the spinal cord send signal directly to the muscle before the brain responds**
 - C. the sensory nervous system signals the muscle to contract without involving the CNS

D. the endocrine system cause the muscles to react immediately

13. What is the resting stage of a neuron called

A. depolarization

B. repolarization

C. hyperpolarization

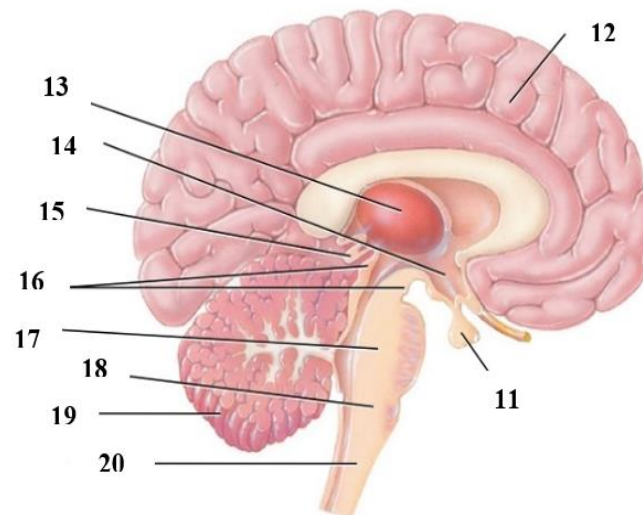
D. Polarization

SECTION B : Labelling Test

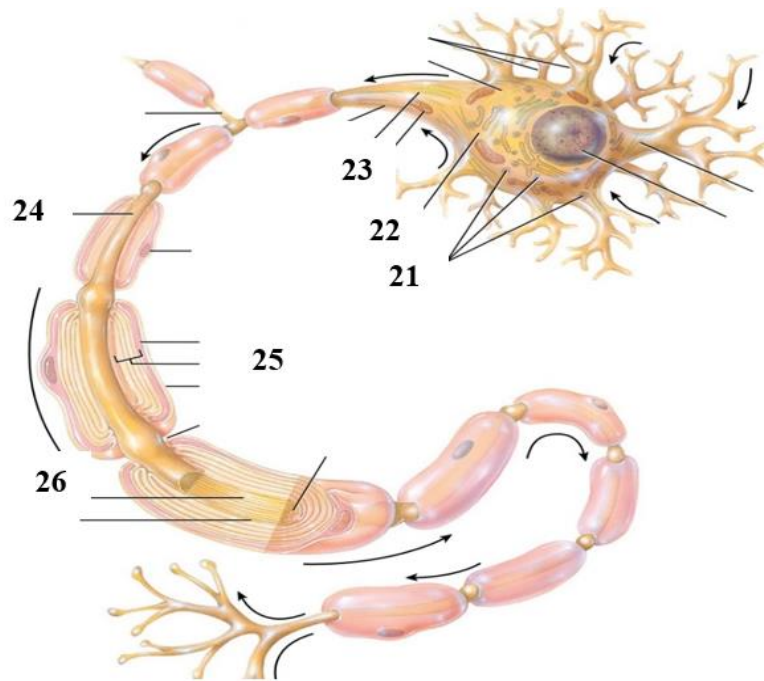
Labelling exercise

Label the diagram using the following list of words:

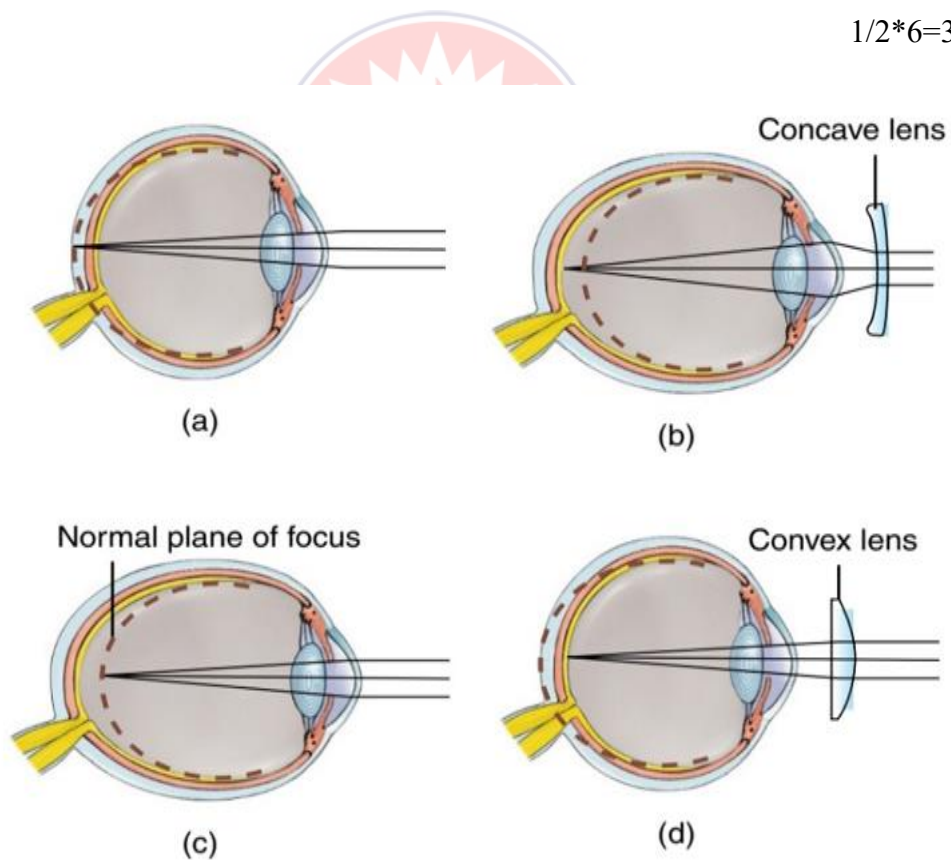
DIENCEPHALON, Thalamus, Hypothalamus, Pineal gland (part of epithalamus), BRAINSTEM, Midbrain, Pons, Medulla oblongata, CEREBELLUM, Spinal cord, POSTERIOR, CEREBRUM, Pituitary gland, ANTERIOR



1/2*10 =3marks



$1/2 \times 6 = 3$ marks



Given diagrams a and c as a case in question, determine the problem and suggest why you chose a corrective measure and justify your choice

Answer

- In c, light rays from a distant object are focused in front of the retina instead of directly on it.
- This happens because:
 1. The eyeball is too long (myopia), or
 2. The cornea/lens is too curved, increasing the refractive power of the eye.
- A concave lens ie in b (diverging lens) is prescribed because it diverges the incoming parallel light rays before they enter the eye.
- This makes the rays appear as though they are coming from a nearer point, so after refraction by the eye's cornea and lens, the rays come to focus exactly on the retina, producing a clear image.

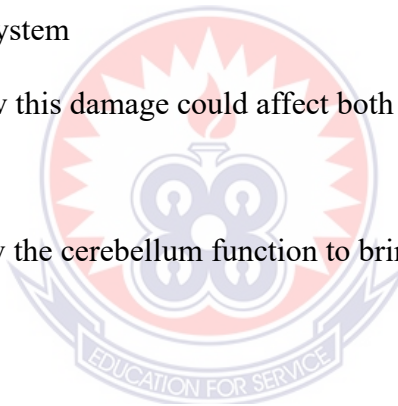
Concave lenses correct myopia by compensating for excessive convergence of light in the myopic eye, shifting the focal point back onto the retina.

Hyperopia (Long-Sightedness)

- Problem: In eye a, light rays from a near object are focused behind the retina instead of on it.
- Causes:
 1. The eyeball is too short (hyperopia).
 2. The cornea/lens has too little curvature, reducing the refractive power.
- Correction with convex lens:
 1. A convex lens converges incoming light rays before they enter the eye.
 2. This shifts the focal point forward, so the rays now fall directly on the retina, producing a clear image.

Section C : ESSAY

1. Explain how the sodium potassium pump helps neuron maintain its resting potential
2. Describe the sequence of events that lead to depolarization during impulse transmission.
3. Explain why impulse travels faster in a myelinated neuron than in an unmyelinated neuron
4. Predict what will happen to impulse transmission if the sodium pumps in a neuron stop working? Give reasons for your answer.
5. A person suffers damage to their spinal cord
 - i. Predict how this would affect communication between the central and peripheral system
 - ii. Suggest how this damage could affect both voluntary and involuntary functions
 - iii. Explain how the cerebellum function to bring about balance in posture.



MARKING SCHEME

- I. The sodium potassium pump actively transport ions across the neuronal membrane using ATP

For every 3 Na⁺ pumped out of the neuron, 2 potassium ions, K⁺ are pumped in. This create a difference in charge with the inside of the neuron being more negative compared to the outside. This difference in electrical charge maintain the resting potential of about of -70Mv which prepare the neuron to transmit impulse when stimulated.

- II. When a neuron is stimulated voltage gated sodium channels open allowing Na⁺ to rush rapidly into the axon. This sudden influx of positive ions causes the inside of the neuron to become less negative and eventually positive compared the outside, this change in polarity is called depolarization and it's the first step in generating an action potential.

- III. In myelinated neurons, the axon is covered with a myelin sheath produced by Schwann cells and the sheath insulate the axon and prevent ion exchange along its length, except at the Node of Ranvier. As a result, the nerve impulse jumps from node to node in a process called saltatory conduction. This makes transmission much faster compared to unmyelinated neurons where the impulse travels continuously along the entire axon.

- IV. If the sodium potassium pump stops working, the neuron would not be able to maintain its resting potential because sodium ions would accumulate in the cell and potassium ions would leak out. Without the normal resting potential the neuron cannot return to its polarized state after an action potential. This means new impulses cannot be generated and nerve communication would eventually fail. In severe cases this could lead to paralysis or failure of vital processes controlled by the nervous system.

- V. The spinal cord is the main pathway that links the brain to the rest of the body. If it is damaged signals from the brain cannot reach the body below the point of injury and sensory signal from those areas cannot reach the brain. This results in a loss in communication on the Central Nervous System and Peripheral Nervous System.
- i. Voluntary movement such walking, writing or lifting the hand maybe lost below the site of damage, for example, a person with spinal cord damage at the waist level may lose the ability to move their legs(paralysis)
- ii. Involuntary processes such as reflexes such as bladder control or even breathing (if the upper spinal cord is damaged) may also be impaired. For example, spinal cord damage in the neck may affect breathing muscles making it hard to breath without assistance.
- iv. The cerebellum plays a central role in maintaining balance and posture by acting as the brain's "coordination center." It doesn't initiate movement, but it fine-tunes, adjusts, and corrects motor activity so the body stays upright and stable. Here's how it works: The cerebellum compares signals from these sensory systems with the intended movement command from the cerebral cortex.
- If there is a mismatch (e.g., you start to sway while standing), the cerebellum sends corrective signals via motor pathways to muscles, especially those in the trunk and limbs, to restore balance.

APPENDIX B

STUDENTS ATTITUDE QUESTIONNAIRE ON CONTROL AND

COORDINATION (SAQCC)

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF SCIENCE EDUCATION

INSTRUCTIONS: On the following pages you will find several statements that you may or may not agree with. You are asked to determine how strongly you feel about the statement from strongly disagree to strongly agree. Please express the extent of your agreement with each statement by placing a tick mark (✓) under the column that best describes your answer. If you want to change your answer, please cross out the tick mark and mark another column.

Demographic Information

Age:

Sex: Male ()

Female ()

	Statement	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
1	I like learning control and coordination more than any other Biology topics					
2	Generally, I feel secure while attempting control and coordination					
3	Control and coordination don't scare me at all					
4	I do not think I can do advanced control and coordination (Human Anatomy) in future					
5	Control and coordination is interesting and enjoyable to me					
6	I think I can handle difficult control and coordination questions					
7	I have been at ease in Biology classes					
8	I am sure I can get good grades in Biology					

9	I do not enjoy learning control and coordination topic					
10	It would not bother me at all to take advanced control and coordination (Human Anatomy) in future courses					
11	I have a lot of self-confidence when answering control and coordination questions					
12	Control and coordination topic usually makes me feel uncomfortable and nervous					



APPENDIX C

STORYBOARD TEMPLATE: IMPULSE TRANSMISSION & EPILEPSY

ANIMATION (GROUP PROJECT)

Instructions: use this storyboard to plan out your animation or interactive project. Each scene should show a different part of the process, from normal impulse transmission to what happens during epilepsy.

Scene 1

Title: Normal impulse Transmission Across Synapse

(normal impulse transmission)

narration or labels:

(in this scene, a healthy brain at a potential of -70mv poised to transmit impulse)

Visuals/Animation

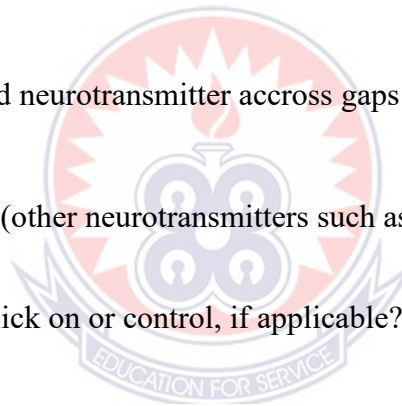
(neurons interconnected neurotransmitter across gaps

‘(acetylcholine)

interactivity (optional):(other neurotransmitters such as GABA/dopamine in a drag and drop model)

(what can the viewer click on or control, if applicable?)

Start And Stop buttons



Scene 2

Title/scene description: Impulse Transmission

(Impulse is represented by glowing sparks)

Narration or labels:

(The neuron upon receiving the impulse will transmit it in the form of glowing sparks, smoothly traveling along axons with directional arrows)

Visuals/animations:

(Arrows lead to sparks)

Interactivity (optional):

Click on start and stop buttons

Scene 3

Title/scene description: synaptic transmission

(impulse prompts the release of neurotransmitters)

Narration or labels:

(Impulse arrives at synapse signals the release of neurotransmitters)

Visuals/animations:

(Calm dim background)

Interactivity (optional):

(what can the viewer click on or control, if applicable?)

--drag and drop to bring an erratic background signals light that overstimulate

Scene 4

Title/scene description:

(Epilepsy attack)

Narration or labels:

(Rapid chaotic neuron activity with a shift of alarming fireball)

Visuals/animations:

(Red to orange hue off flaming fire)

Interactivity (optional):

(What can the viewer click on or control, if applicable?)

N/A

Scene 5

Title/scene description: epilepsy

(Epileptic movement due to excessive influx of rapid signals)

Narration or labels:

(Chaotic brain activity)

Visuals/animations:

(Uneven brain activity)

Interactivity (optional):

(What can the viewer click on or control, if applicable?)

Scene 6

Title/scene description: restoring calm

(Drag and drop different neurotransmitters. both inhibiting and excitatory to see its effect)

Narration or labels:

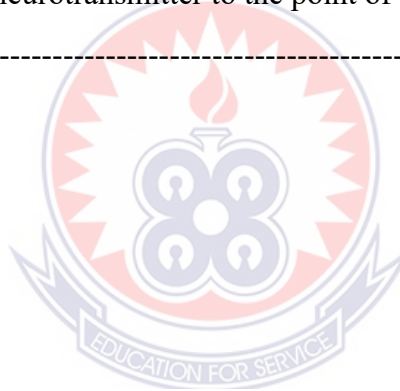
(Dragging and dropping inhibiting neurotransmitter to the point of stimulation restores calm)

Visuals/animations:

(Neurotransmitter buttons)

Interactivity (optional):

(Click / drag and drop neurotransmitter to the point of stimulation)



APPENDIX D

**TABLE OF SPECIFICATION FOR EVALUATION OF SELECTED TOPICS
IN CONTROL AND COORDINATION**

Weeks	Focal Areas	Type of questions	Dok LEVELS				Total
			1	2	3	4	
1	1. Explain coordination and control-	1. Multiple choice questions	0	1			1
	2. General plan of the nervous system	MCQs	0	1		1	2
	3. Generation of impulse	Essay Type QQ MCQ	0 1	3	1		4 1
2	1. Parts of the brain	Multiple choice questions	4	3	3	0	10
	2. The spinal cord 3. Voluntary and involuntary action	Essay Type QQ	0	4	1	0	5
4	1. The reflex arc and action	MCQ	0	1	0	0	1
	2. Peripheral nervous system	MCQ	0	0	1	0	1
	3. Autonomic nervous system	MCQ	1				1
5	1. Protection of the nervous system	ESSAY	2	1	1		4
		MCQS	0		2		2
	2. The structure of the eye	MCQ	4	0	0	0	4
		Essay Type	0	2	2		4
	TOTALS		12	16	11	1	40

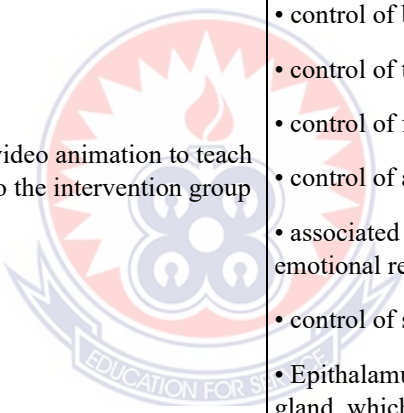
APPENDIX E: LESSON PLAN

DATE/TIME/ DURATION	TOPIC/ SUBTOPIC	SPECIFIC OBJECTIVES/ RPK	RESOURCES/ TEACHING LEARNING ACTIVITIES	CONTENT (CORE POINTS)	EVALUATION/ REMARKS
28 TH JANUARY, 2022	Control and coordination	By the end of the lesson, the student would be able to ;	INTRODUCTION Use a scenario to explain control and coordination.	-Control and coordination: The Ability to receive stimuli integrate it and initiate appropriate response changes in the external and internal environment	What is Control and coordination?
FRIDAY		1. EXPLAIN the term Control and Coordination	Activity 1 1. Guide students to explore the removal of light in a dark room Activity 2 The other half is the group that had to squeeze into a small hot room. Activity 3 Student write a report on how they survived. Activity 4 Use students response to explain the term control and coordination	TEAMWORK AND DISCUSSION Discussion Discussion – To enhance survival – To eschew danger – To maintain internal constancy The Two Main Parts Of The Nervous System 1. The central nervous system (THE BRAIN AND THE SPINAL)	2. Mention the two parts of the nervous system.

			Again, help the student to brainstorm on the importance of responding to stimuli.	2. The peripheral nervous system (INTERNAL ORGANS, GLANDS MUSCLES)	
			5. Use charts to teach the two main parts of the nervous system.	This includes all the nerve processes that connects the CNS to receptors, muscle and glands	
	Parts of the brain	1. Identify the parts of the brain	Use prototype brain to teach parts of the brain.	THE BRAIN. Forebrain- CEREBRUM This is the largest brain structure. It is divided into the left and right hemispheres by the longitudinal cerebral fissure. Each hemisphere can be divided into lobes – occipital, frontal, parietal and temporal. The outer layer of the cerebrum is called the cerebral cortex and is made of grey matter (nerve cell bodies). The layers below this are white matter (nerve fibres). The cerebral cortex is responsible for our conscious mind and consists of interneurons (the neurons that lie between sensory and motor neurons). The cerebral cortex can be divided into functional areas, which were mapped by K Brodmann in 1906, it is important to remember that the areas do not function independently from one another, and damage to one structure may have consequences for another.	3, state to functions each of the • cerebrum • Cerebelum • Medular oblongata

02/02/2022			Use text to explain the anatomic and functional regions of the brain for traditional lecture based group Use animation for the intervention group Animation that explains the anatomical and functional structure of the brain	The first of the functional areas is the motor area and it is subdivided as follows: • the primary motor area – responsible for contraction of skeletal muscles; • the premotor area – involved in fine skeletal muscle movement creating the manual dexterity associated with repetitive or learned motor movement (e.g. tying a shoelace, learning to paint); • Broca's area – responsible for the motor movement required to produce speech; • The frontal eye field area – controls voluntary movement of the eyes. The second functional area is the sensory area, responsible for awareness of sensation. It can be divided as follows: • the primary somatosensory area – receives sensory information from the skin and also from proprioceptors in skeletal muscles; • the somatosensory association area – integrates the sensory information being relayed to the primary somatosensory area and provides information about size, texture, previous experience; • the visual areas – the primary visual area receives information from the eye and the visual association	Identify and describe two functional regions of the brain. <i>Expected answers</i> <i>Primary motor area; responsible for skeletal muscles contraction and</i> <i>Primary motor area is responsible for muscle movement and fine motor skills creating the manual dexterity associated with repetitive and learned behaviour such as tying</i>
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		Continue from previous page	Use text and static pictures of the brain for the control group	area help to connect this information with past visual experiences; • the auditory areas – associated with the interpretation of sounds; • the olfactory area – interprets smell information received from the nose via the olfactory nerves; • the gustatory area – interprets taste information. There are many other association areas within the cerebrum that act as communication areas between different functional regions in the cerebrum, such as Wernicke’s area, which is responsible for understanding written and spoken language and is closely associated with Broca’s speech area.	<i>of a shoe lace, Learning to paint etc</i> Broca’s area” it is associated with speech Wernicke’s area: Responsible for speech and written language.
02/02/2022 WEDNESDAY 4TH FEBRUARY, 2022	FUNCTIONAL REGIONS OF THE BRAIN THE HIND BRAIN	Identify the parts of the hindbrain	Use animation for the intervention group Brainstorm on the parts of the hind brain using text books and prototype brain	PARTS OF THE HIND BRAIN Medulla oblongata – relay station for sensory nerves going to the cerebrum. The medulla contains autonomic centres such as the cardiac centre, the respiratory centre, the vasomotor centre and the coughing, sneezing and vomiting centre.. Diencephalon This part of the brain is surrounded by the cerebrum and contains three paired structures: • Thalamus – acts as a relay station for sensory impulse going to the cerebral cortex for integration	III. EXPLAIN THE TERM MEDULLA OBLONGATA.

		Identify the anatomy of the hindbrain	Use video animation to teach this to the intervention group  and motor impulses entering and leaving the cerebral hemispheres. It also has a role in memory. • Hypothalamus – is closely associated with the pituitary gland. it has two main anatomic function (ie it has a link between endocrine and nervous system) The hypothalamus has many functions and these include: • control of body temperature • control of the autonomic nervous system • control of fluid balance and thirst • control of appetite • associated with the limbic system dealing with emotional reactions • control of sexual behaviours. • Epithalamus – this structure is linked to the pineal gland, which secretes the hormone melatonin responsible for sleep–wake cycles. PITUITARY GLAND Is an extention of the hypothalamus. Brainstem The structures that form the brainstem are involved in many activities that are essential for life. The brainstem is associated with the cranial nerves.	
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	The Structure of the Hind Brain		Use illustration for the control group Use video animation for the intervention group	• Midbrain – conduction pathway that connects the cerebrum with the lower brain structures and spinal cord. • Pons – also a conduction pathway communicating with the cerebellum. The pons works with the medulla oblongata to control depth and rate of respiration. • Medulla oblongata – relay station for sensory nerves going to the cerebrum. The medulla contains autonomic centres such as the cardiac centre, the respiratory centre, the vasomotor centre and the coughing, sneezing and vomiting centre. The medulla is also the site of decussation of the pyramidal tracts – this means that the right side of the body is controlled by the left cerebral hemisphere and vice versa. Cerebellum The cerebellum coordinates voluntary muscle movement, balance and posture. It ensures that muscle movements are smooth, coordinated and precise.	
4TH FEBRUARY, 2022 09/02/2022 WEDNESDAY	Reflex arc	Describe the reflex arc and reflex action.	Review reflex arc with the students and brainstorm on how the brain registers pain. how spinal reflex espouses moves for survival, NB	A reflex action is an automatic (involuntary) and rapid response to a stimulus, which minimizes any damage to the body from potentially harmful conditions, such as touching something hot. Reflex actions are therefore essential to the survival of many organisms Reflex Arc It describes the path of a reflex action	By the use of a diagram explain what happens if a hot object is touched

			The static diagram for the control group and the video for the intervention group Review types of neuron in the Integrated Science syllabus	Review (Sensory. Relay, Motor neuron)	
09/02/2022 WEDNESDAY	TYPES OF SENSORY NEURONE		Teach the different types of sensory neuron. Use text and blackboard illustration for the control group Use video animation for the intervention group	AFFERENT NEURON (innervates the sensory receptors conducting impulse away from this to the brain, sensory information for onward transmission to the efferent neuron to the spinal cord and the brain and efferent neuron. Conduct impulse from brain to the effector	Which stimulus neuron carries a heat stimulus from touching a hot object Expected answer afferent neuron
9TH FEBRUARY, 2022 WEDNESDAY	Impulse transmission	Describe the generation and transmission of nerve impulses.	1. Discuss the generation and transmission of impulses.	1. Generator Region This is the part of a sensory neuron where the stimulus is first detected — often the receptor endings of the neuron. When a stimulus (like touch, temperature, or pressure) is strong enough, it causes changes in the membrane potential here. 2. Generator Potential This is a local, graded potential produced in the generator region in response to a stimulus. • It's not an all-or-nothing response. • The stronger the stimulus, the greater the	Explain the following as related to impulse transmission 1. Depolarization 2. Polarization 3. Repolarization

Wednesday			2. Carry out activities to demonstrate the reception of stimulus. Discuss their findings(Brainstorming) Use text and static diagrams to teach this to control group	generator potential. - If the generator potential is strong enough to reach the threshold, it triggers an action potential. 3. Threshold Value This is the minimum level of depolarization needed to trigger an action potential. - Usually about -55 mV in neurons. - If the generator potential reaches or exceeds this level, voltage-gated sodium channels open and an action potential begins. 4. Action Potential This is the rapid and massive depolarization of the neuron's membrane followed by repolarization. - It's an all-or-nothing response — once started, it travels along the axon without losing strength. - During this process: - Sodium ions (Na^+) enter the neuron → depolarization - Then potassium ions (K^+) leave → repolarization 5. Resting Potential This is the normal, stable electrical charge across a neuron's membrane when it's not sending a signal.	
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				- Usually around -70 mV. - Maintained by the sodium-potassium pump (Na^+/K^+ pump) and selective membrane permeability.	
11/02/2022	Impulse Transmission	Explain how impulse is transmitted across synapse	Use video animation	 1. Role of the Golgi Apparatus and Mitochondria in Synaptic Knobs	
FRIDAY	Transmission of impulse across synapse	Student use storyboard to design the animation with neurotransmitters types and their function the help of their ICT teacher	Review normal impulse transmission Brainstorm on how to create animation involving transmission of impulse. Guide the student to predict intervention strategies-based on understanding gained from the lesson on impulse transmission.	Golgi Apparatus: - The Golgi apparatus in the synaptic knob is responsible for: - Packaging neurotransmitters into synaptic vesicles. - These neurotransmitters (like acetylcholine or dopamine) are chemicals that transmit signals across the synaptic cleft to the next neuron or effector cell.	
11/02/2022	Animation and impulse transmissions by neurotransmitter	Differentiate between neurotransmitter types	Student Response	 Think of the Golgi as a post office, packaging neurotransmitter “messages” into vesicles and preparing them for delivery across the synapse.	
		(Inhibitory Excitatory)	In normal transmission, the impulse travels in a controlled In an uncontrolled impulse, there may be uncontrolled release of neurotransmitter,	Mitochondria: - The synaptic knob is energy-demanding, and mitochondria are there to: - Produce ATP, which is used for: - Synthesis of neurotransmitters - Active transport of ions (like calcium) - Reuptake and recycling of neurotransmitters - Movement of synaptic vesicles toward the membrane for exocytosis	

			The brain receives excessive brain signals which may cause uncontrolled muscle contraction Help the student to use storyboard on appendix z to design a student friendly animation Student can use press button and or drag and drop to stimulate the release of acetylcholine and in normal impulse transmission Student give a long press of induce excessive release of acetylcholine and excessive signals to the brain. The student brainstorm on the condition or disorder been demonstrated	✂ Mitochondria are like the power plants, fueling the entire process of synaptic transmission. ✂ 2. Steps in the Transmission of Nerve Impulses (Across a Synapse) Step-by-step Process: 1. Arrival of Action Potential ○ An action potential arrives at the presynaptic neuron's axon terminal (synaptic knob). 2. Opening of Calcium Channels ○ Voltage-gated Ca^{2+} channels open, allowing calcium ions to enter the synaptic knob. 3. Fusion of Synaptic Vesicles ○ Calcium triggers synaptic vesicles (loaded with neurotransmitters) to move toward and fuse with the presynaptic membrane. 4. Neurotransmitter Release ○ Vesicles release their neurotransmitters into the synaptic cleft via exocytosis. 5. Binding to Receptors ○ Neurotransmitters diffuse across the synaptic cleft and bind to specific receptors on the postsynaptic membrane.	
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			Drag one neurotransmitter to the site of signal and brainstorm on importance	6. Generation of Postsynaptic Potential ○ This causes ion channels to open on the postsynaptic neuron, generating a postsynaptic potential (which may be excitatory or inhibitory). 7. Initiation of New Action Potential ○ If the postsynaptic potential reaches threshold, a new action potential is generated in the postsynaptic neuron. 8. Neurotransmitter Removal ○ To prevent continuous stimulation, neurotransmitters are: ▪ Broken down by enzymes ▪ Reabsorbed by the presynaptic neuron (reuptake) ▪ Or diffused away	
11/02/2022 FRIDAY		Distinguish between voluntary and involuntary actions	Teacher observes and elicits information on what voluntary and involuntary action is.	Voluntary action not under the control of one's will Involuntary action not under the control of one's will	
		Describe the peripheral nervous system	Use a chart to teach the peripheral nervous system Mention the various nerves as i. 12 cranial nerves ii. 31 spinal nerves iii. Parasympathetic nerves iv. Sympathetic nerves	This includes all the nerve processes that connects the CNS to receptors, muscle and glands. It includes the nerves of the face and neck and all the nerves connected to the senses The nerves that connect the body to the surface of the body towards the limbs	

			v. Vagus nerves Use video animation to walk student through the function of the nerves	Parasympathetic nerves it is responsible for activities attributed to relaxed state of the mind. Sympathetic nerves are responsible for any emergency state of the body and or stressful situations.	
		Describe the autonomic nervous system and its function		This consist of nerves from CNS to smooth muscles, like the cardiac muscles, glands etc. The ANS has two divisions that stimulate or increase (sympathetic nervous system) organ activity and the other inhibit (parasympathetic nervous system) organ activity.	
		Explain how the nervous system is protected Use video or animation to teach the other supporting for intervention group	Student brainstorm on the how the brain and spinal cord is protected from their integrated science lessons	CSF Vertebral column Pia matter (inner) Arachnoid matter(middle) Dura matter(outer) Astrocytes form the blood–brain barrier, which gives the neurons an extra layer of protection from any toxic substances within the blood Neuroglia: collection of supporting cells of the CNS includes the schwann cells and the amoe	

				(Microglia oligodendrocytes ependymal)	
		Describe the structure of the eye of the mammal	Use prototype to teach parts of the eye as students observe/ Video to explain accommodation (short sight and long sightedness and presbyopia)	PARTS OF THE EYE CONEA IRIS: a pigmented disc with two sets of muscles regulate the amount of light entering the pupil. LENS: Focus Image of Object on the Retina AQUEOUS HUMOUR ; the liquid medium lying behind the cornea which facilitates refraction CHOROID; Coloured, vascularised preventing internal reflection Conjunctiva; thin transparent membrane lining the inner surface of eyelids RETINA: The light sensitive part of the eye FOVEA: The point on the retina most sensitive to light where the image is likely to be focused.	

20/02/2022 WEDNESDAY	The Mammalian Eye	Describe the Structure of the Mammalian Eye	How images are formed	Light falls on an object It enters the eye Rays from this object is refracted twice; one before the lens By the cornea By the aqueous humour The lens and the vitreous humour Then focused on the foveaa of the retina sends signal through the optic nerve which send the stimulus to the brain which interpret the light into an image of the object. Muscles contract and relax to adjust the lens to focus the image onto the retina The Muscles: Suspensory ligament contract to exert or relax the ciliary muscles that applies forces on the lens to accommodate the image. ACCOMODATION It is the process of adjusting the sizes of the len (relax to make it spherical) to focus the object.	
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			Draw a ray diagram to teach the traditional lecture based group Use video to explain accommodation (short sight and long sightedness to the intervention group)	MYOPIA When light from an object travels through the following media (cornea, aqueous humor, lens, vitreous humour. The image is focused in front of the Retina Correction Concave lens / diverging lens: this lens focuses the light rays from illuminated object by lengthening the focal length causing the image to be focused on the retina HYPERMETROPIA Distant object is brought to focus behind the retina The image is blurry and is corrected by using a converging lens /convex lens Focal length The distant between the centre of the lens and the focal point.	
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