COMPUTER THREE-DIMENSIONAL ANIMATION USE AND ITS EFFECT ON SECONDARY SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDING OF MAMMALIAN CIRCULATORY SYSTEM IN KIAMBU COUNTY, KENYA

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E55F/21661/2020

RESEARCH THESIS SUBMITTED TO THE SCHOOL OF EDUCATION FOR THE AWARD OF MASTER'S DEGREE IN SCIENCE EDUCATION AT KENYATTA UNIVERSITY

AUGUST, 2024

DECLARATION

I Hassan Bob Rogers, student of Educational Communication Technology Department of Kenyatta, affirmed that this master thesis is a unique work of mine, and that this work has not been submitted in another educational institution or university for the award of a Master Degree in Science Education. All adopted or borrowed tables, texts, data, figures, pictures, and graphs, are referenced and cited accordingly.

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DEDICATION

Indeed, without the help, motivation, and encouragement of my supervisors, Dr. Grace Orado and Dr. Mary Nasibi in writing this thesis, it could be impossible in completing my thesis successfully. I appreciate their insights, patience, and guidance. Thanks to everyone who assisted me in completing this work successfully.

ACKNOWLEDGEMENTS

I dedicate this thesis to Sorna F. Sheriff−Academic Dean at Kakata Rural Teachers Training Institute (KRTTI), who provided me the opportunity to study at Kenyatta University. Furthermore, I would like to thank my mother, Sarah N. Flomo, for her unending prayers for me; and also Mr. Abraham Kiazolu for his support and advocacy at the Ministry of Education, Republic of Liberia, for my upkeep.

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ABBREVIATION AND ACRONYMS

AG	Augmented Reality
C3D	Computer 3 Dimension
CG	Control Group
CGI	Computer Generated Imagery
CS	Computer Simulation
EG	Experimental Group
ICT	Information Communication Technology
MCS	Mammalian Circulatory System
SBE	Simulation-Based Education
SRs	Simulation Realities
TEPSS	Thika East Public Secondary Schools

ABSTRACT

The purpose of this study was to rummaged whether computer 3D animation ameliorate students' conceptual grasp of the mammalian circulatory system (MCS), factors and attitudes of teachers influencing C3D−animation in teaching biology in Gatuanyaga, Thika−East Sub−County. The study's scope focused on secondary students and biology teachers in public schools, incorporating C3D−animations in the tutelage of biology. This study−investigation's objectives were to rummage the effectiveness−aftermath of C3D animation in ameliorating protégés' conceptual grasp of the MCS, rummage factors influencing−deploying C3D animation in tutelage of biology, and, precis perspectives of educators−teacher towards deployment of C3D anime in tutelage of biology. The research−methodology adopted quasi-experimental design−which provide evidence linking a specific intervention and an outcome. The study involved 160 Form−Two students, 80 students within each group (control and experimental), and 13 biology teachers. Pretest and posttests were used as students' questionnaires, and educators' questionnaires (precis 5-points) Likert Scale, focused on factors and perspectives of educators influencing deploying C3D−anime. SPSS-Version 25.00 and descriptive narrative were used for data analysis. An independent−t-test was employed to rummage significant apparent−difference with posttest−scores of control and experimental groups after intervention, while descriptive−narratives and frequency−percentages were engaged to analyzed teachers' questionnaires. The study's findings showed that, C3D−anime illustration was concrete in enhancing protégés' cogitation of the MCS and retention of key biological− terminologies of protégés in EG than protégés in CG. The findings also established that; institutions lack resources to support teachers in using C3D−animation, teachers lack confidence, and competency in dealing with technical issues related to C3D, as key factors influencing the use of C3D. The findings also established that teachers demonstrated favorable attitudes toward the use of C3D−animation. In conclusion, C3D−anime is effective in teaching and learning to enhance protégés cogitation of nonconcrete contents in biology related to MCS, couple with teachers' favorable attitudes toward C3D−animation. It is recommended that public schools provide C3D−animation access to biology−teachers and students, and train them in basic animation presentation−skills for teaching and learning.

CHAPTER ONE

1.0 INTRODUCTION

This chapter rivet on the study's background, the problem statement, purpose and , study's objectives. In addition, withal focuses on the research's questions, limitation, and significance. Lastly, it considers the theoretical and conceptual framework. In this chapter the following terminologies were used interchangeably: computer animation and simulation.

Background of the Study

Today's advancement in information technology has breathed up−to−date preference into the relish of computers in classrooms. In this modern dispensation, animations (multimedia technologies) combined with various media, including texts, graphics, and audios, are becoming more and more popular. These technologies allow the outgrowth of multimedia elements to raise educational standards (Ismail et al., 2017). Computer animation is sine qua non in scientific instruction and erudition. Computer Generated Imagery (CGI) also referred to as 3D animation, deals with creating moving digital images. The forthright of computer animation in science tutelage is to create or portray abstract biological processes such as the synthesis of biological molecules, how organs function, and natural phenomena to ameliorate students uptick a vantage conceptual intuit of abstract concepts in learning science (Thalmann & Thalmann, 2002).

There are two primary categories of animations: two dimensional (2D) and three-dimensional (3D). Another name for 2D animation is traditional animation. It is a method use for producing two-dimensional animation with X and Y axes. As previously mentioned, 2D drawings or paintings are made on transparent plastic sheet known as cells in the traditional manner. Images created on these sheets are then integrated into a single image and displayed as 24 frames in a second. When 2D shapes are drawn, they are solely represented as flat values in the X and Y axes, with no depth. Shapes like triangles, squares, circles, and polygons are a few instances of 2D representations; each of these shapes is rendered as an image with its own unique area, angles, perimeter, etc. As implied by the name, three-dimensional animation (3D) uses the X, Y, and Z axes as its three dimensions. Computer−generated objects or visuals are always use in computer 3D animation. Characters and objects can be moved into 3D space using a depth value because these images and objects have lengths, widths, and heights. Experimenting with 3D, 360-degree rotation is possible for images. Three-dimensional (3D) animated graphics resemble realistic images that can be used to simulate biological processes, among other things. To give the video objects more life, animators can work with sophisticated settings like lightings, shadows, and texture effects (Alhumaidhi, 2020).

The conventional learning framework no longer fully meets students' learning styles since it has not kept up with the most recent educational innovations. The use of animation in classroom’s instruction has the potential to improve educational quality. Additionally, animated teaching videos can help keep students engaged while learning. It is feasible to overcome the limited attention span and loss of focus that many students experience. The importance of animation for students may also be demonstrated in the realm of education. Animated learning content can be used in schools for a variety of goals, including explaining complex and difficult concepts in an easy-to-understand manner, making learning more pleasant for students, and presenting new concepts from a whole different perspective. Animation has an important function in increasing students' enthusiasm for studying. Animation draws and piques the interest of viewers since motion is one of the primary qualities that make a graphic visible. Animations due to their distinctiveness, can also improve performance (Krishna & Prasad, 2021).

New visual mediums, including animation, multimedia, and virtual reality, are among the most significant advances made possible by instructional technology. Every new representation is met with enthusiasm at first, but this enthusiasm fades as studies on how it affects learning processes and outcomes yield inconsistent results. Animations are frequently use to demonstrate to students, concepts that are difficult to understand in the actual world, including the shifting positions of continents or the motion of atoms in a gas. Phenomena that are not intrinsically visual, like seed germination, can also be represented with more abstract images. The widespread use of animations nowadays can be attributed in part to the widespread belief that they facilitate learners' comprehension of difficult concepts. Nonetheless, there is often a wide range of explanations offered for this positive outcome. Some individuals think that because animations are so compelling, they can aid in students' learning. On the other hand, some people think that some computational aspects of animations correspond with the mental demands of a learning activity (Ainsworth, 2008).

Animation has advanced significantly from basic curve and geometric-lines to photo−realistic vapid−animated creatures. Almost any thought may be transformed into a visual representation. In teaching and learning, any visual representation can be used to vividly demonstrate content otherwise be arduous to expound; in infrastructure, it can be used to envisage the integral edifice afore erecting the structure start–ups; in engineering, they can be used to effectuate things like fatigue cracking in materials; and in medicine, they can be used to explain medical concepts and conditions. Popularly, animations can be utilized as a teaching kit intended to improve learning headway. The instructor's ability to explain a certain topic, as well as the animation's choregraph ease of exhibition must be examined. In as much as computer animation is an appealing domain of vocation producing seductive visual effects, it should be handled responsibly and with caution (Kainz et al., 2013).

Psychologically, animation can help solve problems by formulating mental imagery. Computer 3D animations improved students' performances by linking conceptual understandings to applications. This approach maintains that students' attention is focused on the outcomes to be achieved by motivating independent action (Fanning, 1994).

Errington (2011) stated that, it is not novel to use computer 3D animation or simulation to bring students closer to a subject or enhance students' conceptual understanding of real-world situations. He further stated that the Ancient Greeks used animation-simulations to express their morals, ethical, and social values to the outside world.

Currently up-to-the minute technological epoch, schooling and learning protocol have indeed transcended old–school methodology to schooling. Biology Education is thought–out to greatly avail from and to a hefty range warrant employment of C3D animation (Bhatti et al., 2017). Educators are turning to animation−based learning to assist in bridging the knowledge gap of learners between academic theories and practical applications. Computer 3D simulation has recently gained credence in educational sectors to narrow the knowledge deficit between theories and applications. There has been a rise in the demonstration of animation to mediate tutoring students' fundamental knowledge and skills (Enu & Nkum, 2019).

There is a long history of animation−simulation model used in military settings and trainings. Lines drawn in the sand with objects like stones and twigs representing topographic features characterized the earliest models of animation. (Kos, 2013).

In 1908, É. Cohl made Fantasmagorie−the earliest animated show, became documented as traditional simulation (animation). The show mostly had twigs characters swaying to-and-fro and tumbling upon various morphinized items, akin wine jug morphing into a plant. (Lamotte, 2022). It was a science instructor named C. E. Reynaud who produced the first animated projection on a screen. In 1877, Reynaud invented the Praxinoscope, and in December 1888, he built the Théâtre Optique. He screened the first animation for the general audience in Paris in 1892. Notably, this movie is the first to be known to use film perforations. His films were sketched straight onto the transparent strip rather than taken with a camera. Early on, computer animation developed along two different paths in the field of animation between the 1960s and the mid-1980s. Initially, academic institutions, research centers, and other establishments with enough funding focused on examining the ways in which computational technologies could be applied to produce dynamic visuals and artistic effects, occasionally unique to novel mechanisms or new animation styles. Conversely, computer-aided production methods and technologies began a commonplace in studio animated film production. Although this led to a hybridization of animation technologies, the impact on aesthetics was initially barely noticeable. On the other hand, when computer animation gained popularity, a number of reference books were written especially for this new discipline and targeted mostly at computer graphics and engineering students (Lamotte, 2022).

The earliest computer animations were effectuated in the 1960s. During this period computer was refined from being a tool for mathematic to one that could be employed for the creation and potrying of natural phenomena. This relates to the notion of hardware, which includes real-time software and user interaction devices. In 1960, William Fetter was recognized as the person who coined the term computer graphics (CG). Because of his work at Boeing, where he used computers to construct 3D models of objects, including a human figure that became known as the Boeing Man, he is frequently regarded as the father of 3D animation (Beane, 2012).

At the start of the twenty-first century, it was clear that computers had heighten the animation industry: computer animation had taken over as the primary method of production for the film industry and other media; and it was also being used as a digital tool for commercial animation. Before the advent of digital media, animation studios shut down their hand-drawn animation divisions and transitioned to the fiercely competitive realm of computer animation. With the success of blockbuster films, 3D digital animation has established itself as the most lucrative kind of animation (Rehak, 2011).

Mudangha et al. (2018) stated that after World War Two (WW II), animation-simulation became increasingly important in many fields of studies. J. V Neumann and S. Ulam both mathematician used animation expound how the nervous system function amid WW II. In 1968, a group of students from the English Students Simulation Organization (ESSO) developed a game called Business Game to be used in the classroom. The initial developments occurred in the realm of teacher's education, but the movement quickly spread to secondary and tertiary levels of education. The United States is the birthplace of many of the earliest animation or simulation-based approaches to Biology Education. Early attempts to use animation−simulations in the classroom rivet on the social sciences. The perpetration of animation−simulations within teachers' traininh−education is widespread across the globe, especially in the West. Mudangha et al. further pointed out that, due to the pivotal role animations played in the postmodern trend toward interactive Biology Education, computer animations are now inescapable.

Conceptual understanding is a thorough understanding of the fundamental concepts that underpins biological principles, laws, theories, and processes. Furthermore, it involves a situation in which students can recreate diagrams (drawings) and explain biological phenomena without using rote procedures. In addition, pupils are let to decipher decisions and apply his/her knowledge through active participation. The goal of teaching science and biology has shifted from academic performance (student obtaining high marks) to conceptual understanding. This new shift is intended to discourage rote learning and to teach students how to present, analyze, and make generalizations using drawings (diagrams), graphs, tables, terminologies, or symbolic criteria when learning science.

Students learning biology in secondary schools are faced with problems related to biological concepts (Ghazali & Zakaria, 2011).

To reap the benefits of animation in teaching, teachers' attitudes must be carefully considered. These attitudes have a significant influence in superintending and forecasting futurity prosperous implementations of technologies in institutions (Islahi, 2022). According to Akram et al. (2022), adopting computer animation into teaching practices requires teachers to have the right attitudes, knowledge, and technological competencies. But obstacles stand in the way of teachers attempting to incorporate computer animation into biology classes; which is one of the issues this study sought to address.

According to Noori (2020), attitudes of teachers ultimately determine how information technologies−computer animations are commission in the schooling headways; which makes them crucial to the success of computer animation integration in the classrooms. Teachers attitudes affect students' future conducts apropos to the use of computer animation, in addition to their initial acceptance. Morara (2021) stated that understanding teachers' attitudes toward incorporating computer animations are important because teachers' attitudinal barriers can manacle the acceptance of new technology in teaching. Negative attitudes of teachers toward computer animation can cause instructors to harbor skepticism apropos the worthiness of computer animation in instructions, thereby unwilling to adopt said media in his/her teachings.

Employing C3D animation in Biology Education to investigate the aftermaths of picturesque intricacy on the exposition (drawing and interpretation) of cell's organells structures was carried out by (Jenkinson &Mcgill, 2013). According to Jenkinson and McGill findings, visual details displayed by animations benefitted students regardless of their prior knowledge. Furthermore, selective high-lightings of pre-attentive features - this technique directed students' attention to thematically significant display features (biological process). The findings further suggested that this approach helped students avoid developing misconceptions when interpreting biological processes based on diagrams.

In Turkey, Cakiroglu and Yilmaz (2020) investigated how C3D animation affect proteges' conceptual comprehension of basic computer component units. The investigation was initiated within two classrooms, involving 34 protege in grade 10. C3D animations were employed in classroom exercises and homework exercises (assignments). An IQ−concept exercise was chosen to identify students' mis−conceptions and interviews were administered to explicate the gains in students' comprehensions. The findings demonstrated that C3D animations improved students' abilities to identify and correct misconceptions by themselves. In addition, students reported that computer 3D animations helped them in understanding the basic concepts of computer units better by, concretizing, pausing, slowing down, enlarging and replaying the animations videos.

Fayzullayeva and Ergasheva (2021) from a pedagogical standpoint investigated the psychological aspects of pedagogical 3D animation transformation in education. The study findings indicated that, the paramount point of incorporating animation-simulation in science education is to make content more accessible and easier to grasp for students, and to improve students' conceptual understandings and learning outcomes. It is important to remember that, while computer animation based pedagogical design can enhance students' conceptual understandings, its ultimate goal remains genuine instruction; not the creation of technological media for entertainment. Furthermore, the researchers pointed out that the most important thing is to develop learning resources that are interesting and lead to measurable outcomes. Computer animation projects in science education are designed to ease the assimilation of cognizance−knowledge and conceptual compression of biological processes. Since pedagogical design is focused on students and their needs, these animation-simulation projects should be effective, interactive, and cherished by learners.

The potential of computer 3D animations in enhancing students' visualization abilities and lessening learning challenges associated with fundamental mitotic (cell divisions) concepts was investigated by Mnguni and Moyo (2021) in this study, sixty-seven, ten grade students from a South African school were purposively sampled for the investigation. The data obtained was gathered using pretest and posttest. Mnguni and Moyo's findings showed that students' conceptual understanding of mitotic division and drawing skills improved when they interacted with animation that depicted the cell division (mitotic) processes. In summary, computer animations help students visualized information better, boosted students' motivation and comprehension of biological processes better.

In a study done by Sahin (2006) the researcher perused literature on the application of computer animation in biology education. The researcher reviewed various kinds of computer animations, including symbolic animation, experiential animation, conceptual animation, and integrating animation, as well as some excellent examples of each. The reviewed found that even though computer animation (simulation) cannot completely replace laboratory activities; they do offer beaucoup of advantages in traditional mode of learning as well as distance learning. The researcher further noted that, the integration of computer animations by biology teachers were crucial to the success of using animation in science classrooms, particularly when teaching content using diagrams.

A research was carried out by Elangovan (2018) to investigate the effects of animated caricatures in identifying and lessening protégés' delusion about cell divisions. The study involved 136 Malaysian biology students. The experimental group was acquainted by the researcher employing animated cartoons, meanwhile, the control group was instructed through the lecture style. This study implemented a quantitative approach−pre-test and a post-test to investigate the effects of the intervention. The results outlined the treatment group’s understanding of cell divisions improved, and the reduction in misconceptions were significantly lower, while students in the control group understanding showed no significant improvement. This study's results highlighted the value of animated-cartoons in helping learners avoid common misconception- misunderstandings.

A research was done in the USA by Whitworth et al. (2018), involving 515 high school students. The researchers concluded that biology teaching aids in integrating interactive computer 3D simulations in laboratories have wider use as teaching and learning tools for biology activities or lessons. The researchers also pointed out a substantial improvement in the post-test results of individual student after laboratory posttest interventions.

One of the fundamental ideas in chemistry is chemical bonding. Several subjects covered in chemistry curricula revolve around theories and models of chemical bonds. Without understanding chemical bonding, students will struggle to comprehend chemistry because they lack the cognitive tools necessary to visualize the microscopic world of chemistry (Taber et al., 2012). The impact of 3D animation as a teaching style on protégé performance and recalling of chemical concept bonding was investigated by Anekwe and Opara (2021). In this exercise, the tools for gathering data were the Chemical Bonding Achievement Test (CBAT). According to the researchers' findings, students in the experimental group who understood chemical bonding by animation achieved better and remembered the principles of chemical bonding than protégé in the control group who learned chemical bonding through lecture method.

Due to the requirement of obtaining a level of scientific literacy, that allows students to engage in active citizenship in contemporary societies, science is seen as a core subject of utmost importance (Digal & Walag, 2019). Two researchers assessed students' conceptual understanding of how to link content from various science subjects and establish relationships between them using Contextualized Self Learning Modules (CSLM) and Non-Contextualized Self Learning Modules (NCSLM). The study's findings suggested that incorporating CSLM and locally available resources with contextualized content could boost protégé self-efficacy in selecting the apt technique for answering a science questions while also promoting higher-order thinking skills among learners (Salvane & Orongan, 2024).

According to Konicek and Keeley (2015) if protégé apply an approach in a contemporary setting, outline it into their own logic, invent a picture of it, or come up with a befitting theme for it, he/she gain an in-depth analysis for such task. Tan et al. (2020) proposed that conceptual understanding is demonstrated when particularity and theorem are comprehended with a keen comprehension, which facilitates their memory and application; alternatively, conceptual understanding is demonstrated when an explanation is applied to specific novel situations that are previously known.

The abstract physiological processes that take place inside the human body are the reason behind secondary school students' learning challenges when it comes to comprehending concepts related to human biology. Wardyaningrum and Suyanto (2018) carried out a study with the goal of enhancing protégé conceptual knowledge of science through Quipper’s school, an online animation learning platform with engaging features that helps students learn biology in a meaningful way. The experimental and control groups' conceptual understandings of science concepts varied significantly, according to the results. The average-mean grade−score of the EG was better−higher than that of the CG. Hence, it was determined well students' conceptual grasp of biological concepts improved when they used Quipper School-an interactive animation online learning platform. In addition, the use of computer 3D interactive animation when employ might obtain similar result.

In Kenya, Akwee et al. (2012) investigated computer animation integration into biology classrooms to determine how effectively it enhances high school students’ understandings of genes and how genes work. The study was done with 240 Form One biology students in Kakamega central district−in public mixed secondary schools (PMSS). The CG was taught in the usual traditional mode (teacher-centered mode) of teaching. The EG in addition was taught using computer animation. The pretest and posttest administered to students were based on the same gene concept. The study duration was four weeks. The study's findings revealed that using computer 3D animations to teach and learn improved the students' understanding of how genes work compared to students within the CG, who were tutor in the conventional way.

Moreover, the application of computer animation in visualizing biology is to enhance students' conceptual understanding of biological diagrams. Biological diagrams are important components prescribed in the secondary school curriculum in Kenya. These biological diagrams prescribed are meant to enhance students' understandings of biological processes. Kenya Certificate of Secondary Education (KCSE) Biology Paper one, two , and three contained questions to assess students' conceptual understanding of biological processes and principles using biological diagrams. These diagrams assessed students for acquisition of varieties of process skills such as observation, labeling, recording, and inferring. Students' performances in Biology Papers one, two, and three reported by KCSE from 2017 to 2021 were poor or not satisfying, as shown in Table 1.1. From the data in this, it can be deduced or speculated that the poor performances of students in Biology Papers one, two, and three could be attributed to inappropriate methods of teaching contents in biology to explain biological processes (e.g., circulations breathing, digestion, photosynthesis, etc.) involving diagrams, as reported in the KCSE general report for biology 2017−2021 section title '3.3.6 General Advice to Teachers.

Table 1.1 Performance in Biology in the Last Five Years in Kiambu County

Year	Mean Scores	Mean Grade
2017	2.269	D-
2018	3.082	D
2019	3.329	D
2020	3.405	D
2021	3.833	D+

Table 1.1 displays KSCE Kiambu County Education Office Analysis Merit List Biology-231 (2021**).** Decimal performances of learners in this table could be stamped to inappropriate methods demonstrated by biology teachers when teaching content involving biological processes (KNEC Chief Examiner Reports, 2019).

Table 1.2 Kiambu County KCSE Analysis Merit List Biology Grades Obtained Per County 2021

County	A	A -	B+	B	B-	C+	C	C-	D+	D	D-	E
Gatundu North	7	12	47	60	78	90	70	95	74	329	585	574
Gatundu South	5	7	27	56	82	121	97	132	133	601	884	679
Githunguri	0	6	19	58	86	130	100	149	141	629	794	661
Juja	90	90	94	100	78	96	59	56	49	184	294	417
Kabete	2	8	25	54	82	100	93	105	89	397	335	299
Kiambaa	0	6	11	35	47	77	68	76	62	322	452	462
Kiambu	14	20	34	66	96	120	94	113	89	307	241	402
Kikuyu	179	171	167	140	107	127	48	63	49	240	293	336
Lari	5	17	38	74	116	140	119	138	111	547	695	478
Limuru	225	87	121	128	136	133	84	86	104	377	486	614
Ruiru	6	21	18	25	34	35	29	67	53	193	336	380
Thika-East	**0**	**0**	**1**	**1**	**3**	**2**	**12**	**11**	**14**	**67**	**122**	**160**
Thika-West	38	92	156	179	154	221	114	122	104	327	354	340

Table 1.2 indicates the grades ranging from A to E obtained by the number of students within each sub-county in Kiambu County. In Table 1.2, it can be deduced from the grades highlighted that students in Thika-East sub-county performed unsatisfactorily. In addition, no student obtained an A, only two students obtained B+ (plus) and B, respectively. In addition, 71.8% (282) of the students obtained D- (Minus) to E.

1.2 Problem Statement

Cynosure on the reviewed of Kenya Certificate of Secondary Education (KCSE) examiners' reports on biology from 2017−2021, it was reported that many students were unable to answer questions based on biological diagrams describing biological processes. Students could identify structures but were unable to explain how those structures were adapted to their functions, as well as the frequent use of misspelled biological terminologies. Moreover, the examiners' report also indicated and recommended that students should be exposed to tasks that required them to observe, analyze, and make appropriate inferences to build a deeper understanding of content, and teachers should incorporate ICT (which also includes computer 3D animation) in teaching biology to enhance students' conceptual understanding of biological principles, laws, processes, terminologies, and to present content accurately.

KCSE Biology Paper one, two, and three relay on biological diagrams to assess students' conceptual understanding of biological processes as well as a variety of skills (labeling, drawing, inferring, and classifying). Students' performances in biology−as mentioned within Table1.1, for the past five−years (2017−2021), students' mean grades fell between D+ (Plus) to D- (Minus), indicating poor mean scores in the study locale-Thika-East sub-county, as reported by Kiambu County Educational Office in 2022. Moreover, in Table 1.2, 71.8% of students from the study locale-Thika-East sub-county performances were reported to fall between D^- to E, which largely indicated students' poor performance in biology. Biology is a subject that requires students to understand many biological processes such as blood circulations, photosynthesis, cell divisions, Deoxyribose Nucleic Acid (DNA) replication, etc. Hence, this study investigated the effect of C3D animation intervention in enhancing protégé conceptual grasp of the structures, functions, and flow/circulation of blood within the mammalian heart, among, Form Two learners in Thika-East Subcounty.

1.2.1 Purpose of the Study

The purpose of this research−was to examine how the use of computer 3D animation enhances the understanding of specific topics in secondary school biology, such as the mammalian circulation system.

1.2.2 Objectives of the Study

This study was guided by the following objectives to:

a) Determine the effect of computer 3D animation in enhancing students' understanding of blood circulation within the mammalian heart.

b) Determine factors influencing the use of computer 3D animation in teaching biology.

c) Establish attitudes of teachers toward the use of computer 3D animation in teaching biology.

1.2.3Research Questions

i. What effect does computer 3D animations have on enhancing students' conceptual understanding of blood circulation within mammalian heart?

ii. What are the major factors influencing the use of computer− 3D animation in teaching biology for conceptual understanding?

iii. What is the attitude of teachers toward the use of computer−generated 3D animation in teaching biology?

1.3 Significant of the Study

The results established from this investigation are expected to be significant in serving as a guide for Biology Teachers to amend and restructure their mode of teaching content to enhance learners' conceptual understanding related to biological processes involving diagrams, thereby discouraging memorization and rote learning, which is in direct opposition to the essence of learning and instruction in biology. Furthermore, the study's outcomes‒findings would be useful to administrators as a guide for supervision during observations in the biology classrooms when teachers are teaching content.

1.4Scope, Limitation, and Delimitation of the Study

1.4.1Scope of the Study

The scope of the study focused on secondary students and biology teachers as study participants within mixed public secondary schools. Moreover, the study was centered around the use of computer 3D animation, focusing on how it enhances protégé's intellectual comprehension of biological processes specifically‒blood circulation in mammalian heart.

1.4.2 Limitations

This research was carried out with Form Two learners within secondary mixed public schools within Thika-East sub-county, and this might limit the findings to other sub-counties. The study made use of electronic devices such as computer and projector. These devices needed to be powered by the institution's power source. Students that were physically challenged in writing as well as deaf and dumb students (impairment in speech and hearing) did not part−take in the research because: the researcher cannot comprehend sign language.

1.4.3 Delimitations

The study population was narrowed to and conducted with Form Two biology instructors and students in county mixed public secondary schools. This category of school was selected because of its heterogeneous students' population (boys and girls). Moreover, the selection of this group was due to limited studies done with this group of students (Form Two Students) on the intervention of computer−generated 3D animation in learning biology. A specific content pertaining the heart and mammalian circulatory system of mammals was chosen Form−Two biology curriculum to be taught using computer 3D animation, illustrating major biological processes and structures involved in blood circulation.

1.5 Assumptions

It was assumed by the researcher that Biology Teachers are full-time employees of the institutions they work for and would be present throughout the working days of the week for participation and to aid the researcher during data collection. The researcher assumed that biology teachers are knowledgeable in their subject matter and have good classroom management skills. The researcher also assumed that schools selected to participate have a stable power supply to power electronic devices to be used as teaching and learning resources. In addition, all respondents would be expected to cooperate and thereby give honest responses.

1.6 Theoretical Framework

A model-based simulation recreates a real-world process or system. A model can be a symbolic illustration of important features, including the characteristics of the organism or procedure of interest (Hodson & Hill, 2014). This study adopted the simulation model proposed by Sharma (2015). Sharma proposed that both physical and digital or computer animation–simulations play important roles in the teaching of science. The term "real model of simulation" refers to physical objects or computer 3D animation that attempt to mimic the actual natural setting of the biological system or phenomenon, such as the use of an artificially made human skeleton to illustrate the arrangement of bones in the various parts of the body or the use of an artificially made "digestive system" to demonstrate the paths taken by food during digestion in the body. This greatly helps improve students' conceptual understandings and makes teaching and learning in biology interactive and concrete. A computer-generated program called a "virtual model" is used to simulate the operation of biological systems to better illustrate how they work. Biology teachers can use computer animation to show their students the steps involved in biological processes like photosynthesis, cell division, the process digestion of food in the body, and protein synthesis. Students can go through the motions of conducting an experiment with the help of software that lays out detailed instructions and simulates lab-like exercises. Sharma's simulation model framework is related to this study in the following aspects: it demonstrates how simulation aids in improving the conceptual understanding of students related to real-world processes involving diagrams (biological processes), which can be vividly explained using simulation, helps students experience and retain long-term memory of what they have learned, improves teachers' performance in content delivery in the classrooms, as well as to allowed students and teachers to have visual experience of biological phenomena which cannot be experimented at the secondary school level.

1.6.1 Conceptual Framework

Depicted in Figure 1.1 in the conceptual−framework, the independent variable was computer 3D animations of the mammalian circulatory system. This variable is also considered as a computer simulation or augmented reality. This variable was used as the treatment or application to teach and demonstrate how the mammalian circulatory system works (structures, functions, blood circulations, and diseases affecting the cardiovascular system), which was selected from the Form Two biology syllabus. The dependent variable was enhancing protégé's conceptual understanding of the MCS, which was considered as the effect of the treatment to be established. The intervening variables include teachers' ICT skills, which have to do with teachers' knowledge of using electronic gadgets like projector, computer animation; teachers' pedagogy skills, which includes teachers teaching skills, classrooms management, and content knowledge as well. In addition, teaching and learning resources such as computers, projector, and stable power supply. Moreover, the intervening variables as shown in the conceptual framework, could significantly affect reaching the independent variable. When these teaching and learning resources are available, coupled with teachers' ICT skills and pedagogical skills, the dependent variable may become easily achievable and evident.

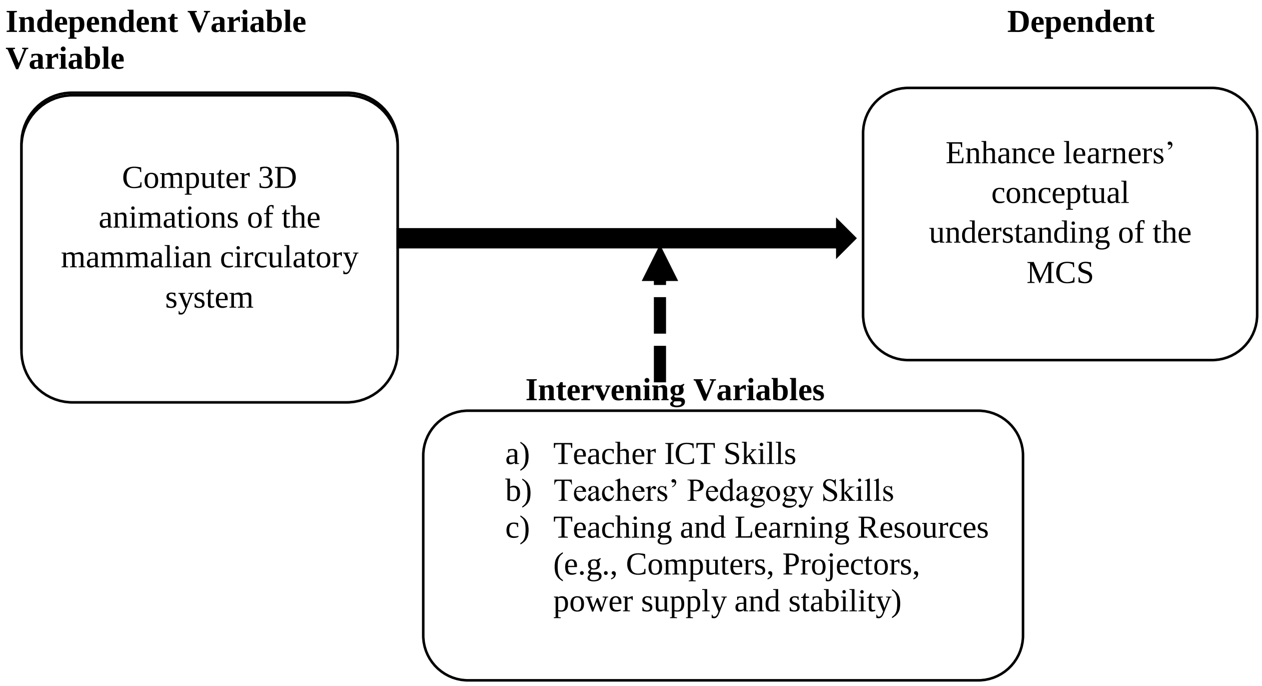

Figure1.1: Conceptual Frame–work

1.7Operational Definition of Key Terms

Augmented Reality- an interactive computer animations view of biological processes.

Biological Process are processes that must take place within living organisms in order to keep them alive.

Computer 3D Animation of the mammalian circulatory refers to videos, animations or simulation which imitate how the mammalian circulatory system works in real life.

Conceptual Understanding refers to the basic or practical understanding of how a biological system works. E.g.: mammalian circulatory system

Content refers to specific lesson in biology, e.g. the mammalian circulatory system to be taught in accordance with the subject syllabus for a particular topic.

Biological Diagram refers to drawing of an organ, organelle, or specimen displaying internal or external structures of an organism**.**

Effects is a change that results when a treatment is done.

Simulation Reality referred to the simulation or animation of the workings of a process that occurs in the real world.

Simulation Representation- usage of physical or computer device for imitation of biological processes

Teacher Attitude refers to behavior or actions displayed by teachers, particularly those activities related to mentoring and steering pupil's learning.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

The cynosures of this chapter is a review of literatures pertinent to this research. These research articles that are reviewed in this chapter offer a variety of contributions and points of view that are pertinent to this research. The reviewed articles concentrate on existing literature on how computer animation (simulations) can be effective in teaching biology to improve students' conceptual understandings of biological processes or phenomena.

2.2 Effect of Computer Animation on Students' Conceptual Understanding

Biology is a difficult subject to learn and teach because of the many interrelated biochemical processes that are complex and abstract to secondary school students. A meaningful instructional discourse, especially in this technological age, necessitates the use of computers by educators to abet instructions and acquisition of knowledge process in schools (Eshun et al., 2019).

Kiboss et al. (2004) demonstrated cell division−cell theory with computer animation (3D animation) involving secondary school students from three different schools. The aim of Kiboss et al. study was to rummage the effectiveness of a C3D animation program on the students' academic's pursuance in biology. A similar study was conducted also by Ali and Equbal (2020) to investigate the effect of computer animation among biology students in senior class and collage in Nigeria. Even though, Ali and Equbal, and Kiboss et al. studies were conducted in different geographical locations, their findings were similar in that computer animations improved students' academic performances in biology. The two studies employed quasi−experimental design. The two researchers' findings were centered around academic performance (students achieving higher marks or grades) only. These researchers did not evaluate students for conceptual understanding of biological processes, which has to do with students analyzing biological diagrams. By employing the MCS, as a demonstration, the current research aimed to bridge the knowledge gap examining the impact of C3D animation on improving protégé's conceptual comprehension of biological processes.

Mwangi et al. (2018) undertook a research project in Kitui County to gauge the implications of computer-animated instruction on students' mathematics misconceptions in loci. The researchers adopted the (MAT) Mathematics Achievement Tests from prior KCSE Exams served to gather facts for the research. There were 207 Form-Four protégés that took part in this study. Nkemakolam et al. (2018) conducted a comparable study in Nigeria to probe the impact of C3D animated instructions on SSS (Secondary School Students') knowledge attainment in chemistry, focusing on gas laws. The study sample consisted of 78 secondary students. The study−inquiry blueprint was−quasi−experimental, and the instrument used for data collection was the Chemistry Achievement Test, from the WASSCE (West Africa Senior Certificate Examination). The two researchers' findings indicated and confirmed that students in the experimental groups who received computer animation instructions had lower misconceptions mean score in mathematics-loci, and significant academic achievement in chemistry-gas laws, respectively, than students who received traditional modes of instruction. These two studies pretest and posttest questions were based on essays and graphs, as it is with gas laws in chemistry and loci in mathematics. The present research sought to remedy the void by focusing pre and post-test items on biological drawing to assess students for conceptual understanding of how the mammalian circulatory system works.

A study was conducted by Aksoy (2013) to explore pupils' learning out-comes are affected by C3D animation intervention, focusing on the Solar System. The study's participants were sixty, seven grade students. The study designed was qui-experimental. The experimental group in this study received computer animation instructions and the control group received videos and power point instructions. The results of the research strutted that in terms of raising pupils' knowledge growth 3D animation technology is superior to traditional style of schooling. In this reviewed study, the researcher's tools (computer animation and videos) were not clearly distinguished. How possible is it that videos did not significantly improve students' academic achievement in the control group? It is well known that computer animations are videos and videos of the solar system are also computer animations. This entails that the EG and the CG received the same interventions. There are two gaps identified in this study: the subject – geography, plus application of treatment. This current study attempted to remedy these voids by employing computer animation in biology and using traditional mode of teaching for the CG only, and computer animation-videos for EG based on the mammalian circulatory system-in biology.

Reddy and Mint (2017) looked into employing video animation in biology classrooms to determine how animations would boost the academic performance of college students in biology. These two researchers taught a lesson on DNA replication and transcription using 3D animation (as their primary teaching tool). Seventy students (freshmen) from the department of biology in the college of education volunteered to take part in the inquiry. The investigators' study design was a tack of mixed−methods. A comparable study involving sixty college students was also carried out by Kwasu and Ema (2015) to probe the aftermath (possible effectiveness) of animated videos on the scholastic achievements of biology protégés which focused on cell and developmental biology concept−reproduction. This study involved sixty freshman college students. The two studies reviewed employed mixed method and quantitative method, respectively. These studies findings indicated that students' academic achievements (scores or grades) were better in CG than students in the EG. These reviewed studies, pretest and posttest did not mention whether any biological diagram was used to evaluate students for conceptual understanding, but instead only mentioned direct essay questions to assess for academic improvement. Moreover, the mixed method approach is not universal or considered useful to investigate such study dealing with experimental and control groups. This current study did adopt quasi-experimental design to narrow the study's gap−methodology reviewed.

Two groups of researchers, Efe et al. (2011) from Turkey, and the Philippines Capuno and Suana (2016) independently carried out separate studies on the aftereffects of C3D model on protégés retention of photosynthesis. Capuano and Suana employed a quasi-experimental design, and assessed students specifically for knowledge and process skills, while Efe et al. employed a cooperative learning strategy to assess students' achievement (academic performance). Despite the two different methodologies employed, the two studies findings showed that students performed better in the EGs than the CGs. It can also be deduced that the computer animation enhanced students' performance disregarding the research approaches used to teach students.

Never the less, these two studies did not use any diagram (biological drawings) to assess students for change in conceptual understanding. The pretest and posttest only consisted of multiple-choice questions. This current study employed C3D animation to investigate its aftereffects on enhancing protégés conceptual grasp of the MCS. In this current study, pretest and posttest were based on the diagram (biological drawing) of the mammalian heart to assess students for significant change in conceptual understanding after the intervention of the C3D animation of the mammalian circulatory system.

In order to gauge protégés' conceptual knowledge and to ascertain whether gender will have a direct aftereffect Gambari et al. (2013) adopted computer animation to demonstrate the digestive system. Yulistia et al. (2024) also evaluated the validity and practicality of computer-animated videos as a supplementary tool for enhancing and fostering learning motivation and understanding of the water cycle among students. Gambari et al. used pretest and posttest as instruments for data collection, while Yulistia et al. adopted the ADDIE Model as their study layout . After cross examining the findings of the two reviewed literatures, it can be concluded that the two investigations data findings of the two studies corroborated the idea that computer animations boost students' marks−achievements irrespective of gender and research the designs employed.

The approach adopted by Yulistia et al. is an instructional approach or planning, which is not feasible for conducting research with the purpose of evaluating students' conceptual understandings. This entails that Yulistia et al. findings only solicited views and comments from experts and students regarding the validity and practicality of computer animated videos for fostering motivation and understanding of the lesson taught. In addition, it can be inferred that computer-animated video is valid and practical for utilization within the realm of educational instruction for students' motivations in the learning process and improving academic achievements.

2.3 Factors Influencing use of Computer Animation in Teaching Biology

The area of communication and information technology, encompassing C3D animation has been the subject of considerable study throughout the last decades on its applications in instruction. The primary variables influencing factors regarding the incorporation of ICT-based computer animation emerging with the educational process, however, are not well established (Eshun et al., 2019).

Dube et al. (2018) conducted a study with 217 randomly selected students using a descriptive survey in order to investigate the important key hurdles inhibiting the mainstreaming of computer animation-ICT within grade−school. The study's conclusions showed that while elementary educators had serviceable−sufficient ICT tools/resources, the key hurdle to the adoption and employing computer animation−ICT in the classroom were teachers' low computer self-efficacy, unfavorable attitudes, and inadequate training. In a parallel study done by Basargekar and Singhavi (2017) probed factors affecting proficiency in the operation of animation−ICT in teaching. The study pool was 515 teachers. The study’s findings showed that there are two main factors preventing teachers from using computer animation−ICT in the classroom: a lack of confidence and motivation. The findings of the studies reviewed confirmed that addition preparation are required regarding, assisting classroom teachers in acquiring the necessary skills to employ computer animation−ICT in their teaching practices and motivating teachers with the necessary supports to integrate computer animation−ICT into teaching. In the reviewed studies, the two researchers did not take into account class size as a factor that could influence the pursuance of computer animation tutelage/learning. This current investigation sought to fill in this gap.

In order to determine the common factors (issues) teachers have when utilizing computer animation into grade−classrooms, Aminullah et al. (2020) administered a scrunity to explore these factors. In this study, 19 teachers participated, which was conducted in 16 public senior schools. Three research tools were used to gather the data: observation, interview, and questionnaire. According to the study's findings, teachers frequently encounter the following factors (issues) when attempting to use computer animation-ICT in the classroom: a shortage in ICT equipment, unavailability of competency, and absence of institutional or administrators’ supports or regulations. These obtained results are matchup with the previous established data of studies reviewed in this section.

Working with 89 nurse educators Fongang et al. (2017) carried out a research to investigate elements bottlenecking or aiding the incorporation of simulation (computer 3D animation) in private and gov’t academies training nurses. The academicians−researchers employed stratified selection and descriptive investigation for institutions selection. Questionnaires with structured format were employed as tools for collection of data by researchers. Results of the research findings pointed to these as factors impeding the use of simulation, which include: limited training of staffs, huge cost to purchase and maintain the animation media, time constraints, and fear of getting wrong feedback due to breakdown or faulty animation media. These factors impeding the usage of the animation media were reported by 65% to 80% of the 89 participants in the study. Kunle and Nwaozuzu (2022) conducted a comparable study to investigate the upsides and drawbacks of incorporating animated cartoons in post-primary schooling system in Africa as a backup educational resource for protégés . This study methodology was based on the Technological Acceptance Model (TAM) of multimedia learning. His findings identified two barriers in incubating−promoting animation learning in schools in Africa's third-world nations, which includes: policy makers readiness to provide supports, hurdles with learning settings, and the educator's persona to include educational level and ICT literacy. He also stated that under estimating any of these impediments render it tedious and time-consuming to realizing the intended purpose of incorporating computer animation into all schools in the 21st century.

The two groups of researchers−Fongang et al. and Kunle and Nwaozuzu findings all pointed to administrators in learning institutions considering the need to help teachers acquire the needed skills and supports in incorporating computer animation into their teaching. In so doing, most of the impeding elements affecting the usage of computer animation/simulation in higher institutions of learning would also be found to impede the use of computer animation in secondary schools. These could likely be resolved at the administration level by providing funds to solve these problems and not solely be considered as the classroom teachers ‘responsibilities**.**

Gaps found in the study reviewed were identified as sample participants who were nurse educators in health education, and the methodology employed was a cross-sectional survey. This current research–study employed a questionnaire consisting of a 5-point Likert scale as a research tool for biology teachers for data collection to fill in this gap, and the results were compared to the findings from the reviewed studies for discussion.

Twelve science teachers from seven schools in Singapore partook in a study led by Vikki et al. (2018) looked in to variables influencing the employment of computer animation in teaching–conveying high school biology. The research methodology was qualitative. The instrument for data collection were interviews conducted face-to-face. Vikki et al. findings pointed out that teachers adopted computer animations for demonstration purposes only to be used for teacher-centered instruction, indicating that teachers could not afford–the cost to make the animation accessible to every learner due to limited facilities (computers, constant power supply), internet availability, and technological knowledge. Moreover, another factor influencing teachers' implementing computer animation in their findings was an urgent need for instructors to wrap up the needful curriculum within a short instructional time constraint. These findings confirmed the findings of Fongang et al. (2017). This subsumes that computer animation should be incorporated into the curriculum for every lesson, which will help teachers and administrators allocate adequate time for teaching using computer animation. The study conducted by Vikki et al. did not investigate whether administrators gave teachers the needed support to employ computer animation in their classrooms and, if so, why teachers became reluctant to do so. This current study captured this as a gap to be filled in by the study's findings.

Habibu et al. (2012) undertook a study to rummage the difficulties instructors faced when using computer animation—ICT, specifically computer animations, in teaching and schooling in Ugandan vocational and tertiary institutions. This probing was descriptive, with 150 teachers participating. The predominant hurdle included a dearth of authentic software , a shortage of gadgets within the teaching environment, sluggish internet, and instructors' enthusiasm for using digital animation, a lackluster curriculum, outdated ICT devices, an acute lack of skilled personnel, minimal administrative aids, and improper training techniques. Souheyla (2019) conducted a parallel study to assess the basic challenges teachers faced when incorporating ICT, specifically computer animation, into class activities. This probing used a qualitative style. The study discovered that, despite these difficulties teachers faced in incorporating ICT−animation in teaching, were keen to incorporate ICT animation in their instructions and exercises−activities. These were the factors that made it difficult for teachers to integrate animation into their teachings: a limited number of ICT−animations tools and the absence of fully subscribed software packages, lack of electrical outlets in some classrooms, lack of effective training**,** poor internet connectivity, and power fluctuations.

Andoh (2012) conducted a survey study to investigate the factors (barriers or variables) having an impact on how instructors endorse and incorporate computer animation (simulation) into the biology classroom. The following factors (barriers) influencing the use of computer animation identified were barriers at the instructor's level, school, and system levels (which has to do with deficits in administrators' supports); supports barriers at the teacher level have to do with the absence of the following: teaching staff's confidence, digital literacy, and didactic training; and monitoring programs, and an inadequate level of animation integration into schools were the restrictions at the school domain/level. The stern structure of traditional educational systems, customary evaluation, constrained the syllabus, and constrained organizational structures are the barriers at the system level. Making a choice on how to address these barriers may be aided by understanding the extent to which these barriers have an impact on learners and institutions. Additionally, stamping the perspective of the current−recent inquiry, educators in public schools who possessed ICT skills to employ animation in teaching biology or any science subjects may attempt to implement their skills to enhance students' understanding of the subject matter. In so doing, teachers are challenged in sourcing and maintaining animations contents, which is considered as a barrier to the continuation of such interventions, leaving teachers with no choice but to return to abstract teaching in a conventional manner. To fill in this gap, computer 3D animations and all other electronic devices were provided by the researcher for this study.

In terms of educators' mindset, it is calculated digital cartoon can help them (teachers) adapt to the requests of their pupils and unique learning preferences; yet, educators need to be at ease using technology and have the time to use them to access the internet and other educational resources, and have administrators support in order to effectively use computer animation as teaching and learning tools. Although computer animations have positive educational benefits, the to which educators are equipped to use technology remains as an ongoing issue (Rojas et al., 2019). Similar findings were emphasized in a study conducted by Husing and Korte (2006). The findings indicated that Spain (52%), Sweden (48%), and Iceland (47%) ranked highest in the number of school computers and internet access. These researchers found that teachers in those countries had the most negative attitudes toward computer animation-simulation (CS). Teachers' advanced age and years of experience were major contributing factors. In addition, these findings entail that when teachers master an approach over many years in teaching a particular subject, they likely resist adopting a new approach due to their long experience and advanced age, thereby thwarting new teaching approaches. The gap found in these reviews are that, the investigators never investigated things that influenced the application of 3D animation in biology instruction. This research was carried out to fill this void by probing such factors.

Onah and Nzewi (2021) conducted a study to identify barriers to integrating animation into science teaching and learning. The study's findings identified the following as major barriers to teachers incorporating animation to teach: dearth of capableness (of teachers), and constraint in accessing resources (administrators). To improve teaching and learning, teachers must receive effective professional development, sufficient time, and technological support. Similar findings were reported by Burns (2023) in the Global Educational Monitoring Report sponsored by UNICEF. The findings in this report showed what teachers perceived to be the primary barriers they encounter in integrating technology (computer 3D animation) into teaching and learning. These barriers were: not improving teachers access to technology and training; radical restructuring and improvement of the quality and utility of pre-service coaching and on the job educators (in-service) career growth; and the requirement of soliciting teachers' voices in policy making and planning. The two researchers' findings echo the need for policy–makers (government officials and school administrators) to invest more in this educational endeavor to transform learning.

2.4 Teachers Attitudes Towards Computer Animation in Teaching Biology

Thanh et al. (2023) conducted a survey to investigate the way that educators–teachers feel about using ICT including their cognitive, affective, and behavior aspects related to computer animation. In addition, the study investigated how teachers' demographic characteristics, such as gender, prior educational level, tenure of service, age (in years), influenced their attitudes–opinions regarding digital animation. The findings revealed that teachers were enthusiastic about incorporating computer animation into their lessons. Furthermore, gender, earlier ICT schooling, educational attainment, years of teaching, and age–in years did not have negative impacts on teachers' attitudes. An analogous investigation initiated by Kuzembayeva et al. (2022) by employing exploratory-descriptive research design to about deploying ICT–based computer animation in schools, and the relationships with qualifications, age, experience, and capableness of teachers with regard to animation in the classrooms. These results indicated that experienced teachers faced fewer barriers to the incorporation of computer animation-ICT classrooms exercises, while age, educational level, and aptitude were not considered as factors affecting instructors' attitudes negatively toward the use of computer animation in teaching and learning. These two independent studies confirmed that teachers' attitudes, age, educational level, and experience did not have any negative impact on teachers' attitudes. The researchers of the reviewed studies did not consider how class size might affect teachers' views about using computer animation may shift depending on the size of their classes toward the use of computer animation. This current study sought to fill in these gap.

To gain a better awareness how secondary school educators in Algeria felt about using computer animation in the classroom, Makhlouf and Bensaf (2021) probed a study to explore the attitudes of high school teachers toward computer animation use in teaching and learning. The findings demonstrated that teachers harbor favorable stance toward computer animation teaching. Additionally, the perused study's findings further showed a negative correlation between teachers' attitudes and their age (as teachers get older). A similar study was carried out in the USA by Blackwell et al. (2014) investigating factors influencing computer animation use in preschool instructions. The study's conclusions demonstrated that early childhood educators' views toward using computer animation to help protégés learned have the biggest impact on technological use, follow by capableness and supports in using technology. Furthermore, teachers' confidence in impacted by the dearth of support, computer literacy, and policies which in turn thwart how well they use computer animation in the classrooms. The findings of the two researchers' targeted teachers' attitudes, though their studies participants were different. The two researchers did not investigate whether teachers received the needed supports and did not use the supports for the intended purpose. This void was intended to be remedied by this study.

Parsons and MacCallum (2020) initiated an investigation to examine the mindsets and views of in-service teachers around the possibilities tied to the employing of computer animation technology, sometimes known as virtual realities in the classroom. Eighty-five teachers participated in a course of instructions where the research was done. Educators had a chance to test out a range of inexpensive computer-animated gadgets in the training section. The end result of the study disclosed that just under 30% of educators responded favorably of animation activities in the learning environment. When queried on how they felt about using animation scenarios in the classrooms, about 73% of educators responded unfavorably or indifferently. Educators expressed opinions such as; they dearth the technological expertise essential to instruct with computer animation graphics; they are skeptical it would be beneficial to pupils; and they are doubtful that it is suitable for senior in high school. When Ndibalema (2014) looked into about computer animation‒a sort of ICT technology‒been used as a teaching tool in Tanzanian high schools. She discovered equivalent outcomes. The conclusion of the study demonstrated that although had favorable mindset regarding the adoption as an educational tool, they donot integrate it in to their lessons since one of the drawbacks addressed was their dearth of experience in utilizing animation as a pedagogical tool.

Whenever each teacher has had the chance to become proficient in the use of technological gadgets in the classroom, animation is likely to become widely accepted as medium of instruction for teachers and students at all levels.

A teacher's attitude is crucial for guiding students' learning. With the rise of smartphones among secondary students, schools can implement regulations to use them for ICT training accompanying cartoons and knowledge of is demanding in educational settings. (Mondal, 2020).

Jansen (2020) executed a study to find out how middle school biology educators felt about using animations demonstrate biology activities. the results of the inquiry demonstrated that a large number of educators had little prior experience computer animation and were unable to envisioned the working of such a program. The information gathered regarding the views and beliefs of educators regarding execution led for adverse results of augmented reality-computer animation in teaching, which include the following: augmented (computer animation) reality consumes a great deal of effort and time; 50% of respondents claimed that working on new technologies takes up a significant amount of their available time and that digital reality keeps them very occupied for teaching, and schools do not promote this teaching and learning technology, as administrators considered such an approach cost-effective. These results presented indicate that educators would prefer to use the conventional method of instruction rather than implementing the more innovative technique made possible by digital media.

A comparative case study was designed by Kumar et al. (2023) to examine educators' perspectives on using computer 3D generated graphics in the classroom environment. An in-depth analysis method was employed to understand the changing perspectives and motivating factors behind teachers' attitudes toward computer animation in teaching. The study's findings established that every teacher demonstrated favorable attitudes toward the usage of computer 3D animation because they have been exposed to 3D animation usage, are ICT literate, and are willing to welcome new media technology in their instruction processes. Županec et al. (2014) carried out a parallel probing with the aim of exploring teachers' attitudes toward graphics animation, addressing the mentality of educators. The results showed that the fifty-four teachers demonstrated favorable attitudes toward computer 3D animation in teaching biology. Additionally, the findings suggested that 87% of biology instructors had a positive deposition for 3D animation, with the other 13% being classified as having a somewhat an unfriendly inclination. Resulted adjusted for teachers for instructors' years of service in the classrooms suggested that their perspectives in the classrooms regarding the use of animation−computer went declining as the got older. The gap found in this study is that: the researchers did not consider whether teachers were able to access online resources to help them in teaching biology using computer 3D animation. In order to close this void, the present research was undertaken.

The perceptions of protégés and instructors concerning their handling of computer animation were examined by Navarro et al. (2024) pertinent to animation−simulation in cell biology laboratory demonstrations. The study included surveys and interviews with 352 participants. Teachers generally agreed with the following perceptions: computer animation is friendly and engaging, boosts motivation, autonomy, interest, and confidence of students in pre laboratory activities were reported as positive attitudes toward computer animation or simulation in laboratory demonstrations. Furthermore, 72% (489 respondents) thought computer animation-simulations could replace old-school or conventional labs, and $\geq$ 90% (317 respondents) opted using computer animation-simulation as preparation tool for applicative exercises. The probed findings also outlined that educators and protégés regarded computer animation-simulation as an effective teaching aid for learning. The general sentiment emerged computer animation-simulation are advantageous as supplementary kit prior to face−to−face experiments.

Fachantidis and Pasalidou (2021) put−through an inquiry of 206 Greek Elementary School educators to evaluate their perspectives and anticipations toward the pedagogical uses for mobile devices AR amine in teaching biology. The educators were trained on the deployment and contacted for their comments on mobile devices using cellphone's AR anime. According to the investigators' conclusions, 67% of educators said they were unfamiliar with the effectiveness of illustration apps for scientific instructions and 98% of educators expressed positive attitudes aimed at deploying smartphone anime in the classrooms, by noting that they include the effectiveness and output of their lessons. Educators' desire to use mobile simulation were also welcome, and they though the mobile were simple to deploy. The results of the investigation indicate that educators will adopt an upbeat outlook toward using anime software in educational settings once they are sufficiently knowledgeable about computerized anime and have mastered the abilities necessary to use such apps for educational aspirations.

The probed actors−primary educators (sample) is the void identified in the review under this theme which was remedied by working with Form Two biology educators in the current study in which its results were juxtaposed to those of others research findings.

2.5 Summary

Many researchers have looked into the practical use of computer animation in teaching science to mimic real-world situations. Animation-simulations were particularly used in professional fields of study such as medicine, military science, and engineering. In the sphere of education, the use of simulation or animation to demonstrate how it improves students' knowledge of the sciences has gained popularity. It is of interest to teach biology by employing computer animation, which has the potential to portray biological processes in living organisms. Teaching biological content using diagrams coupled with computer animation improves students' understanding and make learning concrete.

The reviewed of related literatures, reveal gaps in previous research done. The gaps identified were: Assessment gap−this gap considered how students were assessed. Previous studies assessed students for academic improvements (students getting higher marks or scores) without involving diagrams. This current study sought to assess students for conceptual understanding by formulating test items on a diagram of the mammalian circulatory system after intervention. The geographical gap indicates that, the majority of the literatures reviewed are from Africa and the developed world. It was a challenge finding related research articles from the study locale in Thika-East sub-county. Moreover, the population gap indicated that tertiary students and lower secondary students−Form One and Form Four students were researched, leaving out middle level secondary students. This study was carried out in middle secondary class, to be specific with Form Two students in Thika-East sub-county, to understand how computer 3D animation, when incorporated in teaching biology at middle level in secondary schools, work in improving students' conceptual understandings of biology, when teaching content involving diagrams in biology.

CHAPTER THREE

METHODOLOGY

3.1Introduction

This chapter outlines the present study's methodology utilized to probe this research in Thika-East, which is a sub-county within Kiambu County. This section also cynosure the design of this research, locale-Gatuanyaga, and population of interest, procedure for sampling, and sample size. In addition, this section also includes instruments for data collection, the reliability and validity of primary research tools, strategies for acquiring detail data, ethical and logistical considerations as well.

3.2 Research Design

For this research, a quasi-experimental design was utilized. The purpose of a quasi-experiment is to provide evidence of a causal link between an intervention and an outcome, involving a CG and EG consisting of identical participants−Form Two students (Cohen et al., 2018). This design is relevant in establishing the efficacy computer 3D animation of the MCS is concrete in expanding protégés' conceptual understanding of the MCS. The targeted population for this research was 800 Form Two students and fifty biology teachers. The study locale was Gatuanyaga in Thika-East sub-county. The research tools harness in this investigation were; pretest and posttest (used as learners' questionnaires) and teachers' questionnaires (based upon a 5-point Likert−Scale) for the second and third objective. These pretest items focused on the following: labeling the major structures of the mammalian heart, outlining the functions of key components of the MCS, outlining steps in the sequential flow of blood in and out of the heart, distinguishing between the following blood vessels: aorta, veins, and capillary, naming at least two diseases that affect the cardiovascular system (mammalian circulatory system), and outlining activities or routines that help keep the cardiovascular system strong and healthy. The pretest was prepared based on content or lesson(s) previously done or covered by biology teachers and students before this study was initiated. The researcher went to destinated institutions to verify this information from biology teachers. To make sure that the two tests measured the same constructs; the researcher verified that pretest and posttest had similar test items and structures.

3.2.1 Variables

According to Fraenkel et al. (2012) a variable can be cognitive ability, process skills, aptitude, teaching method, etc. Variables change a person, thing, or situation qualities, properties, or characteristics (DuVall, 2004). The study's variables/parameters are: the independent variable consisted of computer 3D animations of the mammalian circulatory system−for visual display of how the mammalian heart works. The C3D animation of the mammalian circulatory system (intervention or treatment) was projected onto a large white board. The C3D animations of the MCS were administered in these steps: identifying−structures (parts) of MCS (students became familiar with this before moving to the next stage), observing how each structure – works one at a time, and observing the two types of blood circulations in the right and left sides of the heart. In every step, the researcher reinforced that students fully understood key biological terminologies by recapping past lessons before proceeding to the next lesson. The dependent variable was enhancing protégés' conceptual understanding of the MCS (how the mammalian circulatory system works), which was done by administering a posttest to students after the application of treatment. The intervening variables include the use of teacher ICT skills, teachers' pedagogy skills and content knowledge, length of instructional time, and power supply. All these were needed to be available for the effective use of the C3D animation of the mammalian circulatory system/heart to teach for better conceptual understanding.

3. 1.2Research Methodology

The general methodology utilized for the investigation was a quasi−experimental research method. The goal of this research's design is to compare a EG or unit to a CG or unit in order to ascertain the impact of a specific treatment Gopalan et al. (2020). The CG and EG were formed; the EG which was the treatment group taught using computer 3D animation of the mammalian heart during the study, and the CG was tutored using traditional style of schooling. The two groups were assessed with pre and post-tests containing identical test items or questions. The assessment scores were obtained through pretesting, which was intended to evaluate students previous understanding before application of treatment (computer animation of the mammalian heart), and a posttest was written by learners to assess learners' knowledge or understanding after the application of treatment. Data from these tests were collected and entered into SPSS Version 25.0 for analysis to answer and meet the questions and objectives of the research.

3.2 Location of the Study

Thika-East is a Subcounty within Kiambu County. This research locale was Gatuanyaga, which is a locale within Thika-East subcounty. This subcounty has eight public secondary schools, with a population of about eight-hundreds Form Two students, and fifty biology teachers. Thika-East sub-county was chosen as the study setting in Kiambu County based on students' poor performance in the just ended 2021/2022 and previous KCSE biology examinations, in which 71.8% of students scored D- to E, two students obtained B, and no students obtained an A in biology, as indicated in Table 1.2 in the background of the study.

The main economic activity in Thika town is agriculture. The districts surrounding Thika town are appropriately productive agricultural areas. As a result, the districts provide the vital raw materials needed by the numerous industries situated within the town. The environment in those towns allows for the large-scale production of vegetables and fruits like oranges and pineapples. Additional industries comprise cotton textiles, wheat, macadamia nuts, tanneries, auto parts, cigarette manufacturing, bakeries, packaging, and industrial chemicals.

3.3 Target Population

The targeted research's population was eight hundred Form Two students. Thika-East Sub−County has eight public secondary schools. Each school is estimated to have two streams, or sections, for each class. Each stream or class is estimated to have about fifty students. Therefore, the calculated targeted population for this study was eight hundred

Form Two students. Out of the eight public secondary schools, County Secondary Schools consist of 25% (two schools), County Mixed Secondary schools consist of 25% (two schools), and Sub-County schools consist of 50% (four schools), respectively. The targeted population for the number of biology teachers within the eight public secondary schools was fifty.

Due to the few researches undertaken this study locale-Gatuanyaga, Thika-East sub-county with this group (Form Two students). This population was chosen, to research computer 3D animation in biology lessons to improving students' conceptual understandings of biological processes involving diagrams, to be specific, the process of blood circulation within the mammalian heart (mammalian circulatory system).

Table 3.1 Target's Population: Public Schools, Students, and Teachers in TEPSS

Sch. Category	No. of Pub. Sch.	Percent % of Pub. Sch.	No. of Form Two Students	Percent of Form Two Students	No. of Biol Teachers	Percent% of Teachers
County Boys	1	12.5	123	15.4	5	10
County Girls	1	12.5	150	18.7	6	12
County Mixed	2	25.0	205	25.6	13	26
Sub-County Mixed	4	50.0	322	40.3	26	52
Total	**8**	**100**	**800**	**100**	**50**	**100**

Source: Kiambu County Educational Office (2021)

Table 3.1 shows the four categories of schools within the study locale from which the researcher selected two county mixed schools to conduct the research. In this table, 10% (five teachers), 12% (six teachers), 26% (13 teachers), and 52% (26 teachers) represented the targeted number of 50 biology teachers from Boys County, Girls County, Mixed

County, and County Sub Schools respectively. Furthermore, 15.4% (123 students), 18.7% (150 students), 25.6% (205 students), and 40.3% (322 students) represented the total 800 Form Two students from Boys County, Girls County, Mixed County, and County Sub Schools respectively.

3.4 Sampling Techniques and Sample Size

This section focuses on the sampling technique used to select the study participants and the sampling needed for this research.

3.4.1 Sampling Techniques

Simple random sampling technique was implemented to select the required students' number to participate in the investigation. In sample−random sampling, every individual or participant has a comparable likelihood of inclusion within the sampling (Taherdoost, 2018). Students were allowed to write and numbers their names on a piece of paper. Names bearing even numbers were selected to participate in the study. This process was repeated until the 160 sampled number of students were acquired. For biology teachers, purposive sampling was implemented to sample the number of biology teachers. Purposive sampling is adopted when participants is less in the population and the investigator knows that the target population fulfills his/her demands (Bhardwaj, 2019). The two schools sampled out to part take in the study were selected purposively, and assigned as experimental or control group/school purposively.

3.4.2 Sample Size

In the Minimum Required Sample Size (MRSS) according to Bulus (2021) to determine the sample size needed when conducting any quasi−experimental study involving pretest and posttest in a control experiments in the field of education, the minimum required sample size (MRSS), when the alpha value chosen on the table is 0.5, the confidence level is 95%, and the R^2 (the squared relationship between the pretest and posttest) is 0.60. The calculated sample size needed was 160. Therefore, 160 students were sampled out of the 800 Form Two students' population as participants for the study, representing 20% (160 Form Two Students) of the total population. The 160 sampled participants/learners were chosen using simple random sampling, and was split into two equal halves, and distributed equally between experimental and control groups. Thirteen Form Two biology teachers participated in the study.

Table 3.2 Sample grid of Public Schools, Teachers, and Students in TEPSS

School Category	No. of Pub. Schs	Percent % of Pub. Sch.	No. of Form Two Students	Percent % of Form Two Student	No. of Biol Teachers	Percent % of Biol. Teachers
County Mixed	1	50	80	50	7	53.8
County Mixed	1	50	80	50	6	46.2
Total	**2**	**100**	**160**	**100**	**13**	**100**

In Table 3.2, two public county schools sampled out for the demonstration based on the heterogeneous population where the study will be conducted. In addition, the columns labeled percent of teachers and students indicate the fractions or proportions in percent (%) of the targeted population of students and teachers. The thirteen sampled biology teachers for the study in this table represented 26% (13 biology teachers) of the total number of 50 biology teachers in Table 3.1, and the 160 sampled students represented 20% (160 Form Two students) of the 800 Form Two students in Table 3.1.

The deputy principal and biology teachers worked along with the researcher in planning the schedule (for biology class time for Form Two Students) to follow in conducting the study to avoid disrupting others class times. Academic activities or calendar, which was feasible in dealing with the eighty students in each group. Moreover, the researcher worked with one category of school to avoid conflict in the study's findings.

3.5 Research Instruments

The researcher employed pre and post-tests for students and questionnaires for teachers as research tools for data collection during the study. The questionnaires were developed by the investigatos under the supervisions of supervisors and subject teachers. Research tools/instruments are approaches or methods for gathering information during research. In particular, they include questionnaires, interviews, and observation guide (Zohrabi, 2013). For teachers, the primary instruments utilized for data collection were questionnaires focusing on the factors influencing the use of C3D animation encountered by educators, and attitudes of educators (teachers) toward the application of C3D animation. A pre-test was written by learners before the C3D animation application to tap into student prior knowledge, and a post-test was administered after the C3D animation intervention to assess students' knowledge of the mammalian circulatory system for enhancement in students 'conceptual understanding.

3.5.1 Teachers' Questionnaires

A questionnaire is a research instrument prepared or adopted by a researcher for participants to respond to by writing a statement or marking items to express their opinions or indicate their responses (Ary et al., 2010). Using a questionnaire to collect survey data is common and efficient (Cohen et al., 2007). Questionnaires distributed to teachers had two sections. Section A contains data on teachers' backgrounds, while Section B to collects information on teachers' attitudes toward the use of C3D animation when teaching and factors influencing the use of C3D animation. The second objective had six items (on factors influencing the utilization of C3D animation in teaching biology). The third objective had eight items (on establishing attitudes of teachers toward the use of C3D animation in teaching biology). These variables were prepared on Likert 5 point scale for teachers to respond to as disagree, strongly disagree, not sure, agree, and strongly agree to provide data for the second and third objectives. Likert Scale is a measurement tool used to evaluate attitudes, opinions and perception Joshi et al. (2015) which was feasible as measuring tools for the second and third objectives.

3.5.2 Pretest and Posttest (Students' Questionnaires)

Pretest and post-tests (served as questionnaires for students) are research tools that are regarded as being particularly useful and reliable for comparing groups and/or measuring change as a result of experimental treatments to evaluate the effect of an educational program (Biswas et al., 2019).

Pretest administered to learners in both experimental and control groups focused on a specific topic−MCS which was selected from Form Two biology syllabus that had already been taught by teachers. Pretest was scored to assess learners' prior knowledge. After administering the pretest, C3D animations of the mammalian circulatory system intervention was employed to teach for a period of one month. After the intervention period, a posttest containing identical or similar test items were administered to learners within the EG and CG. The ending of the one-month intervention, administration requested the researcher to administer the posttest after two weeks (meant to allow all students to settle fees in preparation for exams).

Pre and post-tests consisted of two sections. Section A, contained information to collect data students' backgrounds, and Section B contained test items (questions) related to mammalian circulatory system. Pre and post-tests were prepared based on KCSE Biology Paper 2 format.

3.6 Piloting of Instruments

A pilot study looks into the viability of a specific concept, if it ought to be continued, and assuming so, why (In, 2017)? A piloted study was initiated in a single secondary school within the study locale−Thika-East sub-county. The school chosen for pilot study was based on similarities to all public secondary schools within the study locale, such as being in the same sub-county, being a public secondary school, having the same academic syllabus for the same grade levels, and following the same academic calendar. Twenty students and six biology educators were sampled out to engage in the piloted exercise. The goal of piloting each research instrument (pretest and teachers' questionnaires) was to help identify and correct ambiguities within each instrument that are beyond the comprehension or confusing in meaning to participants. Results from the pilot study were cardinal in administering research instruments during the main study with ease and clarity.

3.6.1 Validity

Validity is the effectiveness of a research tool to truly measure it intended parameters. By examining how well outcomes match existing theories and additional concepts' measures. An accurate measurement is typically one that is valid; if a test yields precise outcomes, the results should be repeatable (Golfashni, 2011). The researcher used content validity to evaluate items in the research instruments to ensure it trust-worthiness in terms of the research's objectives being investigated. Content validity alludes to the relationship between the testing materials and all subject related activities. the excersise ought to exist at the level of those taking part (Drost, 2004).

3.6.2 Reliability

A trustworthy tool is one that regularly yields the desired outcomes. It shows how reliable data can be collected from a given population using the research instrument. The issue of reproducibility is also addressed (Kothari, 2004). The study used a procedure called "Test-Retest" to determine the reliability and quality of the research tools. In this technique, the researcher presents the same set of questionnaires or research tools to the same participants/groups twice, which will be done through pilot testing of questionnaires and final data collection. To determine the coefficient of reliability, the researcher used alpha Cronbach's statistics. The main benefit of the Cronbach's alpha test is that it can be used to calculate the reliability of items that are not scored right or wrong, such as those found on essay tests and questionnaires with multiple responses or options. For reliable results, a reliability coefficient of at least .70 and above is considered acceptable for the research instrument (Fraenkel et al., 2012). The internal consistency of the instruments, as measured by Cronbach's alpha formula, applied to calculate the reliability of teachers' and students’ questionnaires. The reliability values obtained for teachers' and students' questionnaires were .781 and .747, respectively. The reliability value obtained shows that the instruments are reliable. A reliability is acceptable and considered relatively high when the Cronbach alpha value is .70 – .77 (Taber, 2018).

3.7 Data Collection Technique

A letter of introduction was provided by Kenyatta University, and a permit letter for research was obtained from (NACOSTI). In addition, an endorsement letter from the Ministry of Education was also obtained for authorization to conduct the study. Based on the permits and approvals obtained from the aforementioned authorities, the researcher was allowed to proceed to the research site/schools for introduction and purpose of the study. Administrators and/or teachers informed learners apropos the intended aim of the investigation and to help secure the logistical arrangements and schedules required for ease of data collection. The researcher worked along with school administrators and biology teachers to allocate time during school days for students to provide written responses to pre-test questions to assess students' prior knowledge. Teachers were allowed to brief the sampled students (participants), indicating the information given will be dealt with confidentially and largely for only the research goals.

At the start of the study, the researcher presented to all groups−CG and EG a pretest of identical test items. Eighty students were placed in each group, respectively. Four steps made up the data collection and evaluation process for students: pre-testing for assessing the prior knowledge of students; experimental treatment (intervention application) post-testing to assess the change in students' knowledge (conceptual understanding) after intervention application; and appropriate use and correct spelling of key biological terminologies**.**

Every student was required to answer the pretest items individually in the control and experimental groups. Students were allocated fifty minutes (50 Min.) to respond to pre-test questionnaires. After the administering of pre-test, the researcher proceeded with the application of treatments to the EG while the CG was taught by conventional mode. The C3D anime of the MCS were employed to displayed the stages: blood flow within the mammalian heart, the structure and working of key vessels, including the arteries, veins, valves, and chambers, as well as ailments of the MCS like accumulation of plaque in arteries and which lasted for four weeks. The C3D animations were obtained from Vidmate and varicose veins Unity applications (this application can be accessed from Google Play Store). The C3D animations were projected onto a large whiteboard during presentations for better view, along with biological terminologies describing each structure and process for a better explanation. Teachers who demonstrated with the C3D animations were trained on how to operate the remote, connect the projector to the computer, and focusing the projector lens for a clearer image. This lasted for a day.

In the CG and EG, post-tests were administered to students for 50 minutes. Items on posttest were similar to items within pretest. Both test questions were scored according to appropriate use of terminologies, correct spelling, labeling, and clear sentences. Student marks were recorded and entered into SPSS Version 25.0 for analysis. Pretest and post-test marks of the EG and CG were done by inferential statistics for decision making and interpretation.

For teachers' questionnaires, the researcher inquired about a suitable time for the sampled biology teachers to fill in the questionnaires. Educators were made aware of the purpose of the inquiries was to collect data on their views and opinions regarding the usage of C3D anime in biology lesson involving illustrations. Educators were told that the information they submitted would be treated discreetly and solely to facilitate instructions.

3.8 Data Analysis Technique

Analyzing data is the procedure of gathering, synthesizing, and presenting factual findings. It is essential to answer research questions through the interpretation and analysis of data, make predictions, as well as to draw conclusions (Sutton & Austin, 2015). All data collected from respondents, including mixed were arranged, categorized, and calculated by SPSS 25.0 version.

For objective one, an independent sample t test was done to analyze the data all tests scores for CG and EG. Furthermore, the statistics of the t–test were analyzed to determine whether the application of computer 3D animation of the mammalian circulatory system enhanced the conceptual understanding of students after the intervention or treatment application. The α value of .05 was considered to determine the level of significance between the two mean scores. Objectives two and three data are presented using frequency tables and percentages, that are interpreted and discussed using descriptive narratives.

Table 3.4 Summary of Data Analysis for Each Objective

Objectives	Research Instrument	Method	Statistics	Presentation
Frist Objective	Pre-Test and Post-Test	Quantitative Method	Inferential Statistics: Independent Sample t test	Tabular format and/or narratives.
Second Objective	Questionnaire	Quantitative and Qualitative	Descriptive Statistics	Frequency table, and percentages
Third Objective	Questionnaire	Quantitative & Qualitative	Descriptive Statistics	Frequency tables and percentages

3.9 Ethical and Logistical Considerations

Ethical considerations were strictly followed throughout the duration of the study. The researcher submitted a letter of recommendation issued by graduate school to NACOSTI and the Ministry of Education (MoE) for permission and ethical consideration for data collection in the field. Letters of ethical approval for data collection were presented to the county education office and school principals for acceptance to rollout the research in its locale and chosen institutions. The researcher informed all participants that any personal details they submitted are held in privacy and keenly employed for the intended goal of the research, which is academic. Participants will have the option to remain anonymous or decline to answer specific questions if they so desire.

CHAPTER FOUR

FINDINGS, INTERPRETATION, AND DISCUSSION

4.1 Introduction

This chapter cynosure around analyzing, translating, and deliberation of results that were attained in line alongside the research's objectives. Finding out how C3D anime improves learners' conceptual grasp of the MCS, and including what variables serves as a drawback in influencing C3D anime in teaching biology.

4.2 Demographic Information

This section includes data on teachers' background information, which include gender, and educational level, and for students' gender (frequency of boys and girls).

4.2.1 Response Rate

A total of 160 (N=160) students (boys and girls) were randomly sampled for this study and partition in two groups: EG and CG consisting of eighty students each. A hundred percent response rate was achieved throughout the whole process of data collection.

Table 4.1 Frequency Distribution of Students (Boys and Girls)

Students/Participants	Frequency(f)	Percent (%)
Boys	101	63.1
Girls	59	36.9
Total	**160**	**100**

Outlines in Table 4.1, is a summary of the number of respondents. Out of the 160 students that took part in the study, 63.1% were boys, representing 101 boys, and 36.9% were girls, representing 59 girls, summing up to a total response rate of 100 percent.

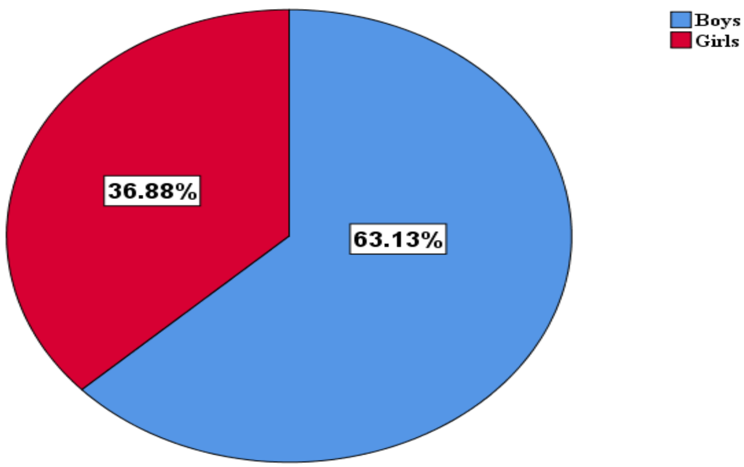

Figure 4.1 Percentage of Boys and Girls

Figure 4.1 is a pie chart displaying the percentage of boys 63.13% (101 boys), and girls 36.88% (59 girls) participated. Figure 4.1 denotes there were more boys than girls in the study's sample.

4.2.2 Respondents' Demographic Data

Respondents' (teachers') background demographic was collected from thirteen biology teachers within the study locale in public secondary schools. Teachers' demographic information included their gender, and educational level.

Table 4.2 Demographic Data of Respondents (Biology Teachers)

Gender	Frequency(f)	Percentage (%)
Female	7	53.8
Male	6	46.2
Total	**13**	**100.0**
Highest Edu. Level	**Frequency(f)**	**Percentage (%)**
Master	1	7.7
Bachelor	12	92.3
Total	**13**	**100.0**

Table 4.2 displays the gender and educational level of respondents (teachers). Males made up 42.6% (six males) and 53.8% (seven females) of the thirteen biology teachers sampled.

4.3 C3D Animation Effect on Learners' Conceptual Understanding

The first paramount objective in this research aimed to ascertain how C3D anime boosts learners' grasp of how blood circulate within the MCS. Data for this objective were collected from students' scores on pretest and posttest, which were used as students' questionnaires. Moreover, key biological terminologies were included in every computer 3D animation, protégés in the EG interacted with, and protégés in the CG were tutored key terms in biology by the lecture style.

4.3.1 Pre-Test Scores

The researcher presented to EG and CG a pretest of identical test items, such as restricted essay questions (labelling) and short essay questions (needed one or two sentences as answers). An independent sample *t*-test test (which compares and determines whether there is statistical evidence that the means of two independent groups are significantly different) was performed to determine whether there was a significant difference between the experimental group and the control group pretest scores. As per the statistical result no apparent distinction−significant in comparing the EG and CG pretest scores. For the EG pretest scores (M = 6.06, SD= 4.490) and CG pretest scores (M= 6.69, SD= 4.350), t (158) = .89, p= .37. Hence, since the *p-value is* > .05; it was determined that the two groups of students' conceptual understanding were of equal capacity (level) or did not show any significance difference, which required the research to continue. Below is a table displaying the mean scores and *SD* only for the two groups pretest scores.

Table 4.3 CG and EG Pretest Means and SD

	Groups	N	Mean	S.D.
Pretest	Experimental Group	80	6.06	4.490
	Control Group	80	6.69	4.350

Moreover, the researcher observed that protégés in the EG and CG were challenged in spelling and the use of appropriate essential biological terms in answering pretest questions. Essential biological terminologies misspelled by both control and experimental groups are represented in Table 4.4 and as a graph in Figure 4.2 .

Table 4.4: Frequency of CG and EG Key Biological Terminologies Misspelled in Pretest

Key Biological Terminologies Misspelled	**Control Group Frequency of Misspelled Terms**	**Experimental Group Frequency of Misspelled Terms**
Aorta	4	17
Artery	18	17
Atrium	32	35
Capillary	39	31
Deoxygenated	17	25
Inferior vena cava	24	25
Oxygenated	17	22
Pulmonary	26	37
Superior vena cava	28	11
Tricuspid	12	15
Ventricles	22	37
Total	**239**	**272**

Table 4.4 displays the frequency table of cardinal terms misspelled by learners in the CG and EG. The summed frequencies of wrongly spelled key biological terminologies for the

CG and EG are 239 and 252, respectively, which indicates that learners in CG and EG had the same footing of challenge in spelling key biological terminologies.

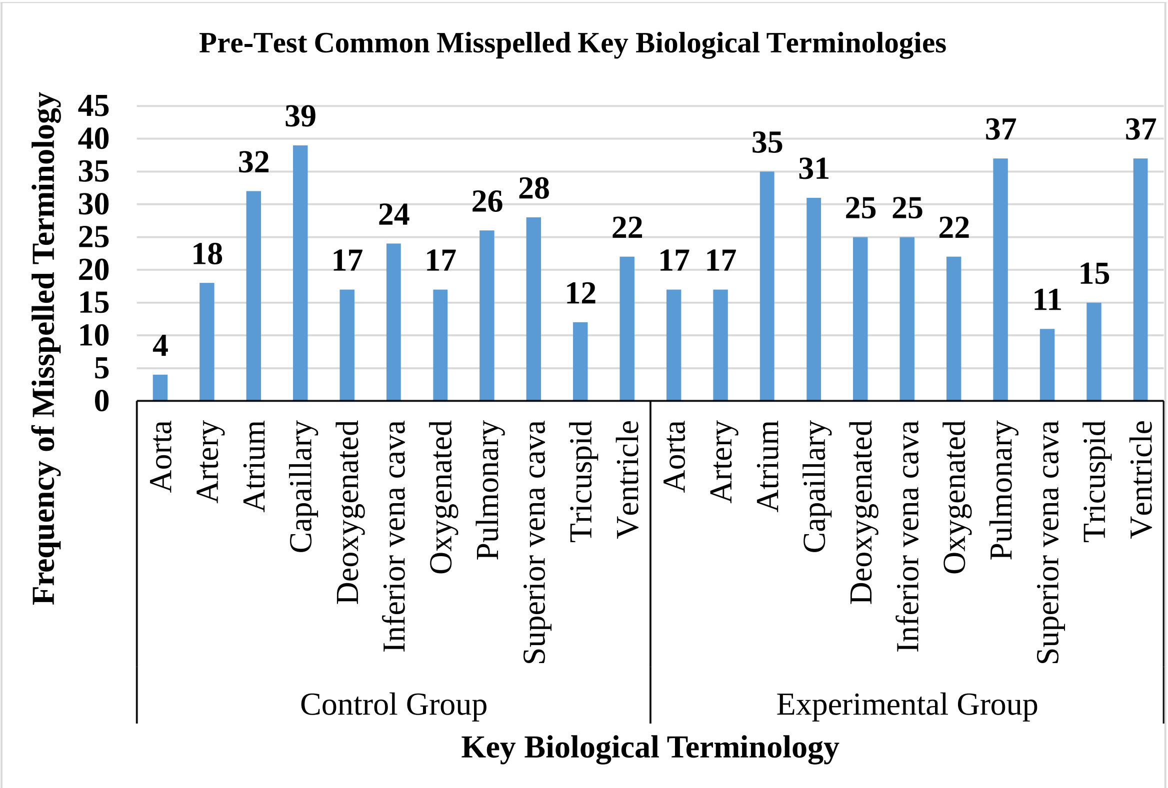

Figure 4.2 Pretest Comparison of CG and EG Key Terms Misspelled

Figure 4.2 indicates pretest key biological terminologies wrongly spelled by CG and EG. This further indicated that, students not understanding key biological terminologies as well as being able to correctly spell and use biological terminologies served as a barrier to enhancing students' conceptual understanding as well. The combined frequencies of key biological terminologies misspelled were 239 and 272 for the control and experimental groups, respectively.

4.3.2 Post-Test Scores

After administering pretest, the researcher assigned the EG to receive 3D computer anime instruction, while the CG received traditional tutoring style lasting about 31 days. In addition, two weeks were given by administration for students to settle fees payment for preparation for end of term exams. The researcher waited for the two weeks to elapse before administering−posttests. Usage of appropriate cardinal terms, correct spellings, labeling, and clear sentences were noted while scoring the posttest for the two groups. Posttest scores were recorded−coded into SPSS Version 25.00 for analysis.

An independent samples *t*-test (which compares and determines whether there is statistical evidence that the means of two independent groups are significantly different) was calculated−posttest scores for the CG and EG to rummage whether there was a significant apparent difference between the EG and CG posttest scores. The results indicated an apparent significant difference between the two groups posttest scores. For the EG posttest scores (M= 27.70, SD= 9.119) and CG (M=13.32, SD= 5.694), $t(158) = 11.96$, $p < .001$. Hence, since the p-value is < .05; these results emphasized that C3D animation of the mammalian circulatory system was concrete in boosting leaners' conceptual understanding of the MCS. Below is a table displaying the CG and EG Mean Scores and SD.

Table 4.5 Control and Experimental Groups Post-Test Means and Standard Deviation

	Groups	N	Mean	SD
Posttest	EG	80	27.70	9.119
	CG	80	13.32	5.694

Table 4.4 displays the means and standard deviations pertaining posttest results for the EG and CG.

Tale 4.6 Summary of Means and SDs for Pretest and Posttest

Groups	Mean−Pretest	SD Pretest	Mean−Posttest	SD Posttest
EG	6.06	4.490	27.70	9.119
CG	6.69	4.350	13.32	5.694

The data in Table 4.5 displays the CG and EG mean scores and SD of these two tests only for ease of comparison.

In addition, the application of the treatment-C3D animation of the mammalian circulatory system, key biological terminologies were included and accompanied by every animation the researcher employed during the study for the experimental group. This further enhanced protégés' retention of cardinal biological terms, which can be attributed to have significantly increased EG mean. protégé within the CG were tutor cardinal terminologies using traditional style−teacher centered which was not weighty in boosting flashback of cardinal biological terminologies of students within this group. The proportion−frequency of widely and wrongly spelled terms are displayed in Table 4.7 and as graph in Figure 4.3.

Table 4.7: Frequency of EG and CG Key Biological Terminologies Misspelled in Post-test

Misspelled Terminologies	Control Group Frequency of Misspelled Terminologies	Control Group Frequency of Misspelled Terminologies
Aorta	23	8
Artery	26	8
Atrium	26	7
Capillary	24	4
Deoxygenated	20	11
Inferior vena cava	15	14
Oxygenated	19	10
Pulmonary	25	8
Superior vena cava	20	15
Tricuspid	19	7
Ventricles	24	15
Total	**203**	**107**

Table 4.7 displays cardinal terms misspelled in the posttest. It can be deduced that the experimental group frequency of key misspelled terminologies was significantly lower than the control group's frequency of key misspelled terminologies.

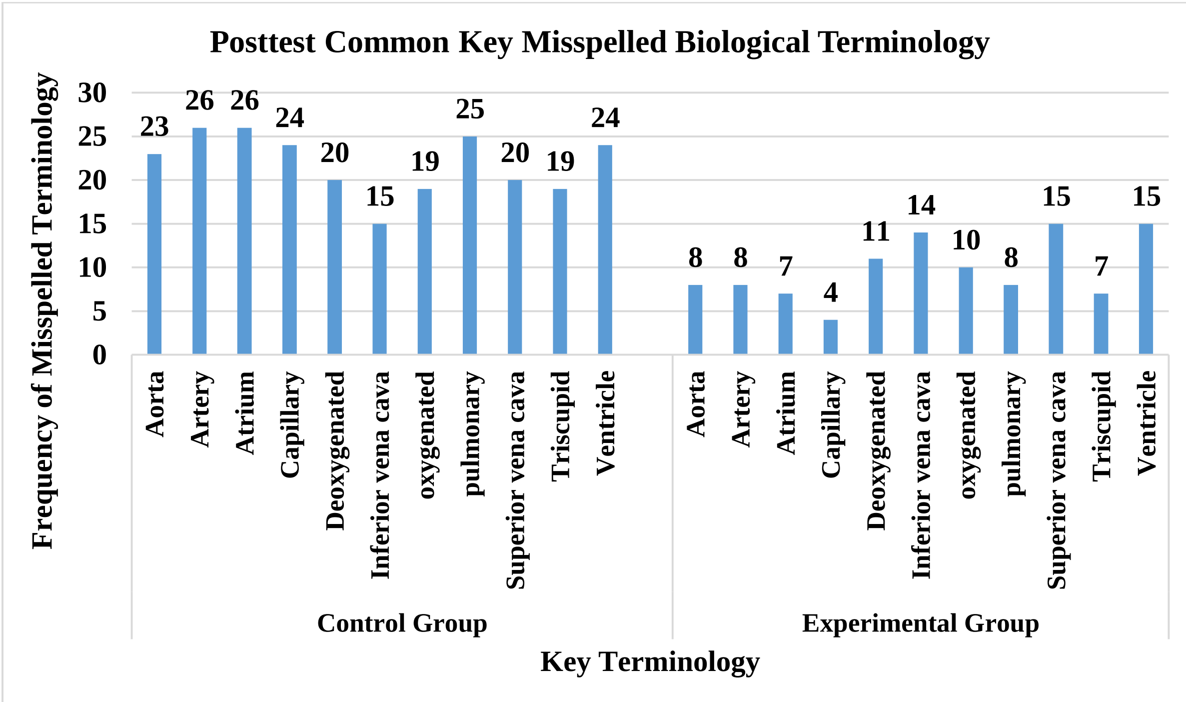

Figure 4.3 Juxtaposed of EG and CG Posttest Key Terms Misspelled

From Figure 4.3, it can be deduced that C3D animation accompanied by key biological terminologies significantly enhanced students' retentions−understandings of key terms within the EG. The aggregate frequencies of these misspelled terms fell from 272 in the pretest−Figure 4.2 to 107 in the posttest−Figure 4.3 (representing a decrease >50%) of misspelled words for the EG. Moreover, students within the CG's retention of key biological terminologies did not seem to improve. Cardinal terminologies misspelled aggregate frequencies of pretest were 239 in Figure 4.2, while for the post-test it was 241 in Figure 4.3 for protégés CG.

The study number one objective was to ascertain how C3D anime beef−up protégés' mental grasp of the MCS. The result of this demonstration align with previous demonstrations evaluating the benefits of C3D anime to beef−up protégés' conceptual grasp in biology and related sciences. In this current study, the experimental group's retention of the MCS surpassed that of the CG. In addition to the demonstration findings, protégés in the EG retention (correct spelling and meaning) of key biological terminologies were also enhanced more than students in the control group. A related demonstration by Efe et al. (2011) used computer−anime to investigate how protégés' achievement levels and biological retention are affected when photosynthesis is taught through computer animation. The results showed that after the intervention period, protégés in the EG out smarted protégés in the CG.

Moreover, the current study's' findings also ascertain the findings conducted by Mwangi et al. (2018) from Kenya on the aftermath of anime illustrations on protégés' misconceptions in math−loci and Nkemakolam et al. (2018) from Nigeria on the effect of anime instruction on secondary protégés' achievement in chemistry−focusing on the gas laws. They stated that computer animation instructions were successful in reducing students' misconceptions in mathematics-loci and enhancing students' achievements in chemistry−gas law, despite the different fields of study. Furthermore, Reddy and Mint (2017) findings confirmed the current study findings. Reddy and Mint proposed in their findings that anime, whenever relied on for imparting theoretical topic such as genome copying, anime positively improve protégé aggregate academic retention in the EG, while also building protégé enthusiasm due to the interactive aspect.

Despite, for C3D anime to be fruitful in beefing up protégés' conceptual grasp of abstract concepts in biology involving secondary school students, teachers need to acquire basic skills in using computer animation for instruction and not to be used for teacher center instructions Vikki et al. (2018). To step-up protégé understanding of conspectus biological concepts and achievements, C3D anime are to be recommended demonstrations and learning, rural learning school where practical is a challenge.

4.4 Factors Influencing the use of C3D Animation in Teaching Biology

The second objective of this investigation was to rummage factors influencing the use of C3D anime in teaching biology. Data were collected using teachers' questionnaires. The questionnaire had eight items and designed based on a 5 points Likert Scale from one to five (Strongly Disagree, Disagree, Not Sure, Agree, and Strongly Agree). The use of a Likert Scale in this instrument was meant to measure respondents' attitudes to a particular question, statement or option that best aligned with their view.

Table 4.3 summarizes the responses of teachers toward each statement. A viable measuring tool for the second objective is the Likert scale, which meant to evaluate attitudes, opinions, and perceptions. Teachers' questionnaire for this objective had six items.

Table 4.8: Summary of Frequencies and Percentages of Factors Influencing C3D Animation

		Types of Response		
		D Disagree	N S Not Sure	A Agree
No.	Statements	F(%)	F(%)	F(%)
1.	C3D can help me to teach many new things in teaching biology	1(7.7)	0 (0)	12(92.3)
2.	I am able to use computer 3D animation in teaching biology	2(15.3)	3(23.1)	8(61.6)
3.	The school has enough resources to help me teach biology using computer 3D animation	4(30.8)	2(15.3)	7(53.9)
4.	I am able to access online resources to help me in teaching biology using computer 3D animation	1(7.7)	1(7.7)	11(84.6)
5.	The class size is too large to allow me to teach biology using computer 3D animation	10(76.9)	0 (0)	3(23.1)
6.	I am not able to deal with technical problems involving computer 3D animations	6(46.2)	3(23.1)	4(30.7)

From Table 4.6, it can be deduced that out of the six statements, three statements were identified as the major factors influencing the operation of C3D anime in teaching biology based on educators' responses, namely statements two, three, and six. Statement two states: I am able to use C3D anime in teaching biology. Nearly forty percent of educators disagreed with this statement. Statement three which states: The school has enough resources to help me teach biology using C3D animation. More than forty-five percent of teachers disagreed with this statement, and statement six states: I am not able to deal with technical problems involving computer 3D animations. More than fifty percent of teachers agreed with this statement. For respondents who chose 'Not Sure' for statement number two, the researcher considered those respondents to lack the confidence needed to teach biology using C3D.

For statement number two, 15.3% (two teachers) disagreed, which can be interpreted as lacking the confidence needed to present biology lessons using C3D animation. Moreover, 23.1% (three teachers) also were not sure to have ability (confidence) to teach biology by employing C3D animation during instruction. Combining these two percentages which summed up to 38.4 % (five teachers) representing nearly half of the thirteen teachers having low confidence/ability in teaching biology involving C3D animation**.** Capitalizing on such judgement the researcher windup that nearly half of the sampled teachers are not confident with teaching biology using C3D animation, but instead preferred the conventional/traditional mode of teaching biology.

For statement number three, 30.8% (four teachers) and 15.3% (two teachers) disagreed and were not sure respectively, that their institutions have enough or the required resources (such as projectors and computers) to aid them to teach biology using C3D animation. Combining the percentages of teachers who disagreed and were not sure that their institutions have the needed resources summed up to 46.1 % (six teachers) representing nearly half of the respondents sampled. The researcher considered a deficit in instructional resources as a major factor influencing the use of C3D animation in teaching biology.

In addition, 30.7% (four teachers) indicated that they lacked or have a deficit in dealing with technical problems relating to C3D animation. Whereas 23.1% (three teachers) were not sure or to have the basic and required skills (ICT) needed to deal with C3D animation when teaching biology. Combining these two percentages summed up to 51.8% (seven teachers) representing slightly more than half of the sampled respondents (teachers) who lacked the basic ICT skills to deal with C3D animation.

Majority of the teachers-more than 80% (10 teachers) agreed that they are able to access C3D animation online resources to teach biology, whereas a combined percent of 15.4% (two teacher) disagreed and were not sure they were able to access online resources to aid them in teaching biology using C3D animation. Since slightly more than half of teachers were not able to deal with technical problems involving C3D animation entails, the majority of the teachers who are able to access C3D online resources will only use C3D animation for their personal use and then resort to the conventional mode of teaching of what they have learned from the online resources they have accessed.

The findings of the second objective, which deals with factors influencing the demonstration of c3D anime in tutoring, support and agree with findings from educators in the field of education. The major factors influencing the use of C3D animation in teaching biology identified during this study were: teachers lack confidence or ability to teach biology by employing C3D animation during instruction. This finding confirmed the findings of Fongang et al. (2017), such as the intimidating nature of the animation/simulation and fear of getting wrong feedback, which portrays a lack of confidence and basic skills needed when employing animation in teaching biology. The next major factor influencing C3D animation was institutions not having enough of the required resources (such as projectors and computers) to aid teachers to teach biology using C3D animation. This thwarts the willingness of teachers to do more in easing the difficulties in enhancing students' conceptual understanding of biological concepts. This finding was also confirmed by Andoh (2012), which he referred to as a hurdle of ICT instructional resources at school/institution level.

Another factor was biology teachers not being able to deal with technical problems relating to C3D animation when teaching biology. Slightly greater than one–half of the aggregate figure of biology teachers lack such skills. Fongang et al. (2017) findings on factors impeding the use of simulation in public and private institutions training nurses, concord with this finding as well. Teachers with such a deficit will always prefer traditional mode of teaching than to employ C3D animation to teach biology. Another factor identified as a major influence of C3D animation was teachers not being able to access C3D animation for teaching biology which was reported by less than a quarter of the participants. This aligned to the high cost and upkeep of internet availability and limited facilities in public schools. Even though this number seem to be small it reflects a negative profound effect in enhancing practical conceptual understanding of considerable number of students being taught by these teachers at the secondary school level, where practical laboratory is a serious challenge. Vikki et al. (2018) reported similar findings when working with twelve biology teachers from seven schools involving computer animation.

Class sizes in the study locale was not considered to be a major factor posing challenge to teachers employing C3D animation in teaching biology. This was indicated by slightly more than two-third of respondents. Moreover, class sizes were considered to be moderate (40-50 students) throughout the study.

4.5 Teachers' Attitudes toward Computer 3D Animation

The third objective was rummaging educators' attitudes apropos the deployment of C3D anime when teaching to enhance students' conceptual understanding. Statistics amassed from educators–teachers germane their perceptiveness, which most explicated their perceptiveness–attitudes apropos C3D anime. A viable measuring tool for the second objective is the Likert scale, which utilized to evaluate attitudes, opinions, plus perceptions. The questionnaire for this objective had eight items.

Table 4.9 Summary of Frequencies and Percentages of Teachers' Attitudes Toward C3D Animation

		Types of Response		
		Disagree D	Not Sure NS	Agree A
No.	Statements	F (%)	F(%)	F(%)
1.	I use C3D anime to teach biology	4(30.8)	2(15.4)	7(53.8)
2.	No support from the admin. implement C3D anime to teach biology	12(92.3)	0 (0)	1(7.7)
3.	C3D anime make learning biology Interesting	0 (0)	0 (0)	13(100)
4.	C3D anime beef up my lecture skills	0 (0)	0 (0)	13(100)
5.	I'm confident working with C 3D anime in teaching	1 (7.7)	3(23.1)	9(69.2)
6.	Deployment C3D anime in teaching demands admin support	1(7.6)	2(15.4)	10(77.0)
7.	3D anime in biology helps to capture protégés' attentions	0 (0)	0 (0)	13(100.0)
8.	C3D anime permit easier illustration of biology than instructing without C3D	0 (0)	1(7.7)	12(92.3)

Cynosure on the replies amassed and summed in Table 4.7, educators had generally good sentiments of 3D amine. The overwhelming number of educators 100% (13 teachers) believed that C3D anime biology classroom instructions. This may be due to the scenario that a large proportion of those questioned conceived utilizing C3D anime to teach biology rendered the subject more fascinating, catches protégés' and captivate them during the course of instruction. As a consequence, protégés' conceptual grasp rose, so as did the subject delivery charismatic of the teachers.

Further, a large proportion of those surveyed, assumed that using 3D anime in classrooms boost protégés grasp of the information (lessons) offered by educators when contrasted to instructing without it. nevertheless, to attain the aims teachers require administrative support at all levels. Approximately, 77.0% (10 instructors) agreed with this assertion. Instructors solo cannot find and manage these tools at a reasonable cost. With administration assistance these drawbacks can be lowered, enabling educators to attain their targets when using C3D anime to teaching this subject.

Likewise, an aggregate percentage of 46.2% (six instructors) stated that they do not use C3D anime to teach biology, whilst roughly well over half—53.8% (seven instructors)—agreed to use it. If biology educators are not using C3D anime in their lessons, it may be given that they lack the courage and basic skills sufficient to work through technical issues with the anime. Administrators can close this gap by providing the appropriate ICT training, which will enable instructors to acquire these competencies and self-assurance to do so.

Whereas 92.3% (12 instructors) said that administration concurs with them−minority −7.7% (one instructor) acknowledged with the statement that they do not receive any kind of assistance from the administration to use C3D anime in biology lessons. Additionally, a total of 30.8% (4 instructors) expressed uncertainty about their ability to use C3D anime in biology lessons, whereas 69.2% (nine instructors) said that they could do so.

The findings of the third objective, which dealt with teachers' attitudes toward computer 3D animation. In the classroom−biology instructors exhibited good sentiments regarding the usage of C3D anime to boost students' conceptual grasp. A large proportion of the respondents consented that using C3D anime to teach biology rendered the subject more engaging, held protégés' attention during class, made it much simpler for them to understand the information that educators put forward, and improved the capacity of educators to impart the usually abstract biological materials taught. Comparable conclusions were made by Fachantidis and Pasalidou (2021) in their research of 202 Greek primary educators, who indicated that 98% of them felt that computer animations increased the effectiveness, fulfillment, and output of their lessons.

Another numerous traits listed by Županec et al. (2014) that adversely impacted instructors' views regarding computer animation in biology education is teaching background. They went on to say that as educators aged and get not much familiarity with computer anime in the classroom, their perspectives about its utilization become less favourable. Stamping from educator's assertions that C3D anime requires an immense amount of time and energy for design and display, as well as making protégés being dependent on educators for knowledge Županec et al. attributed this negative attitude to teachers. In contrast to the conclusions drawn from Županec et al., a large proportion of educators' preference was for the employing of C3D anime, hence the researcher did not discover that teaching experiences had a detrimental impact on the views of educators regarding C3D amines.

However, Blackwell et al.(2014) findings on educators perspectives in using 3D anime which includes limited support and lack of computer knowledge and norms−policies undermine educators' optimism, which subsequently in turn affects the use of 3D anime in teaching negatively, validate the findings of this current studies.

CHAPTER FIVE

SUMMARY OF THE FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This study's goal sought to ascertain the impact of computer 3D animation of the mammalian circulatory system on enhancing secondary learners' conceptual of the structures and functions of the mammalian heart. This section presents a succinct–summary of findings, draw conclusions and makes recommendations stamping from the findings. The final section of the chapter gives suggestions on possible topics for future investigations.

5.2 Summary of Findings

This theme envelopes–summary of the major outcomes related to the three objectives of this study.

5.2.1 Effect of C3D Animation on Students' Conceptual Understanding

Finding out how computer 3D animation beefs up protégés' cognitive grasp of the structures and functions of the MCS was the study's primary goal. Based on the question of whether there was a difference in conceptual understanding and retention of biological knowledge between students instructed with C3D animation (experimental group) and students instructed with traditional methods (control group) dealing only with chalkboard and chalk (teacher centered). The research findings established that students instructed with C3D animation on mammalian circulatory system had higher academic achievements–significantly higher compared to students taught by the traditional methods. Computer 3D animation was utilized in this study to convey abstract concepts through aesthetically appealing, interactive animations and graphics that helped students focus on the real mechanisms underlying the mammalian circulatory system's functioning. Furthermore, the findings of this investigation revealed that C3D animation was genuine in ameliorating students' conceptual understanding of abstract ideas taught in biology, notably the mammalian circulatory system.

5.2.2 Factors Influencing usage of C3D Anime in Teaching Biology

The investigation's second goal was to ascertain factors influencing the use of C3D anime in teaching biology. The study established three major factors influencing the use of C3D animation, which include: teachers lacking the basic skills in teaching or presenting biology−content utilizing C3D animation, institutions lack of resources to assist instructors in teaching biology using computer 3D animation; and teachers lacking the basic ICT skills needed to use C3D animation effectively.

5.2.3 Teachers' Attitudes Toward Computer 3D Animation

Determining educators' attitudes surrounding the incorporation of C3D animation in biology classes to ameliorate students' conceptual grasp was the third goal of this investigation. Furthermore, the info obtained in this part was used to explore the following question: What perspectives do educators have on the usage of computer 3D animation in biology classrooms?

A large proportion of educators—92.3%, or 12 teachers—embodied positive sentiments regarding the use of C3D animation to help students acquire ideas that are tough or abstract in the teaching and learning of biology. The vast majority of the educators panned out that using C3D animation boosted their charisma to teach biology. Likewise, opinions on the use of C3D anime by biology educators weren't shown to be detrimentally affected by age. A large percentage of those surveyed, who are educators, said they are keen to employ C3D anime in biology classes even if it takes additional effort and resources to plan C3D anime lectures. Protégés' favourable perspectives on C3D anime are certainly influenced by their positive mindsets of teachers around it, which makes it easier for them to learn difficult biological ideas through visual aids. The higher proficiency in the post-test results served as testament to this.

5.3 Conclusion

Three primary conclusions were drawn in light of the study's aims, data, and findings: that educating protégés about biology's abstract ideas with 3D anime is a fruitful strategy. The post-test means for the CG and EG show that 3D animation can boost protégés' proficiency in biology classes.

The research results showed that the three main factors that were found to have a negative impact on the use of C3D anime when teaching were: educators lacked the basic skills needed in C3D animation presentation; teachers had deficit in dealing with basic technical skills related to C3D animation, and institutions lacked resources to assist teachers in using computer 3D animation. For the third objective of the study's outcomes, majority of educators had an upbeat view concerning computer-C3D imagery and were keen to include it into their lectures to help protégés better understand physiological processes that were challenging for them to retain when tutored via traditional techniques. Based on the study's findings, it ought to be said that employing the computer 3D ameliorate students' conceptual knowledge of the MCS more than using a traditional teaching paradigm. Additionally, the 3D animated depiction of the mammalian circulatory system inspired biology instructors and students. Additionally, biology instructors thought of using bio 3D animation as an instructional instrument in their classes to improve both their ability to present knowledge and their students' conceptual grasp of nature's abstract phenomenon.

5.4 Recommendations

Considering the study's findings and conclusion, the following recommendations were made:

1. Schools' administrators (principals) and County Educational Officers should make available C3D animations to teachers and students of biology in secondary schools as well as in computer libraries so that teachers and students can engage with C3D animations relating to the topic being taught.
2. Teacher training institutions include C3D animation presentation as a requirement during practice teaching for biology teachers to acquire basic presentation skills needed for 3D animation.
3. To lessen the drawbacks biology educators, suffer while seeking 3D anime, school administrators abet in acquiring teaching 3D anime.

5.5 Recommendations for Further Studies

The following are recommendations for further studies:

1. Since the current research only looked at biology and was conducted in publicly funded secondary schools, comparable research should be undertaken at the junior grade level to increase the usage of computer 3D animation effectiveness in enhancing students' conceptual understanding when teaching biology.
2. These gadgets (cellphones and tablets) are cheap to maintain, popular, and simple to carry. Studies should be conducted on how to employ these devices into the classrooms for 3D animation lessons.
3. A study should be conducted to determine how biology teachers might be motivated to incorporate C3D animation for every lesson they teach in their classrooms.

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APPENDICES

APPENDIX I : TEACHERS' QUESTIONNAIRE

Dear Teacher,
I am a student studying science education to be specific biology education at Kenyatta University in The School of Educational graduate studies program. I'm doing research to find out how using computer-generated 3D visuals improves students' comprehension of how blood circulates in mammals' hearts in Kiambu County

Please write (✔) as your response to each question.

Section A: Background Information

Gender: ________________________ Age: _____________________
Highest level of education
Ph.D. [ ] Master [ ] Bachelor [ ] Diploma [ ]

Others
[indicate]:____

Area of Specialization: ____

Names of subjects: ____
Duration of Teaching in years: _________________________

SECTION B: TEACHING BIOLOGY USING SIMULATIONS
Table 1 Shows statement about teaching using Simulations. **Please write (✔) as your response to each question**

	Statement	Strongly–disagree	Disagree	Notsure	Agree	Strongly–agree
1	Computer 3D animation can help me to learn many new things in teaching biology.					
2	I am able to use computer 3D animation in teaching biology					
3	The school has enough resources to enable me teach biology using computer 3D animation					
4	I am able to access online resources to help me in teaching biology using computer 3D animation					
5	The class size is too large to allow me to teach biology using computer 3D animation					
6	I have a deficit in dealing with technical problems involving computer 3D animation teaching					
Teachers Attitudes toward computer 3D animations						
1	I use C3D anime to teach biology					
2	No support from the admin. Implement C3D anime to teach biology					
3	C3D anime make learning biology Interesting					
4	C3D anime beef up my lecture skills					
5	. I'm confident working with C 3D anime in teaching computer 3D animations in teaching biology.					
6	Deployment C3D anime in teaching demands admin support					
7	3D anime in biology helps to capture protégés' attentions					
8	C3D anime permit easier illustration of biology than instructing without C3D					

APPENDIX II: PRE-TEST

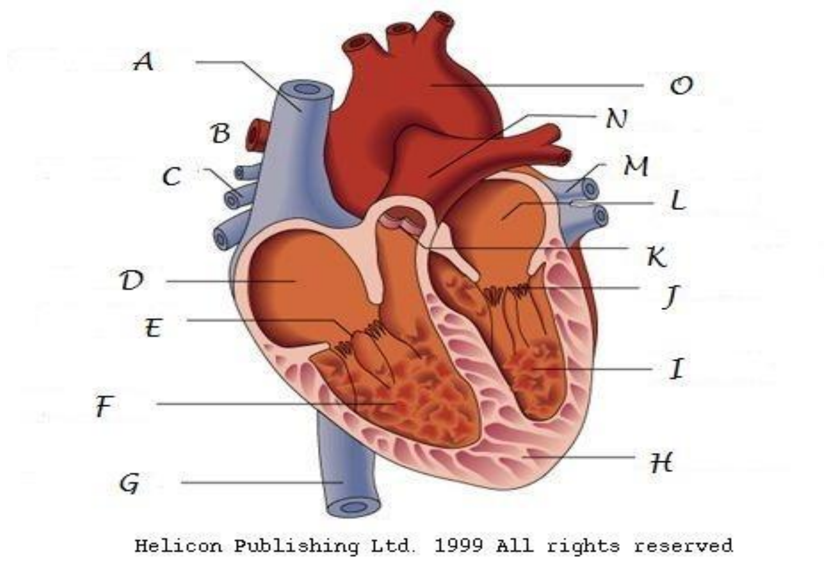
BIOLOGY WRITING ASSESSMENT   50 Points

Content in the Pretest were taught by biology teachers previously

Gender…………… Age: …………………. Form: …………. Time: 50 Minutes Score………….

SECTION A

Instructions: Answer each question in the space provided. The following questions are based on the Mammalian (Human) Circulatory System. Refer to the diagram below to answer all the questions in this section.



1. What is the name of the structure labeled **N**? **(1points)**

____

i. Describe the function(s) of the structure labeled **N** in brief. **(3 points)**

____
____
____
____
____

2. What is the name of the structure labeled **M**? **(1 points)**

____

i. Briefly describe the function(s) of the structure labeled **M**. **(3 points)**

____
____
____
____
____

3. Outline the flow or pumping of blood in the heart. **(5 points)**

____
____
____
____
____
____
____
____

4. Explain the term systole and diastole in the contraction of the heart muscle. **(5 point)**

____
____
____
____
____
____
____
____

5. Outline the passage of blood flow from the aorta to the vena cava. **(5 points)**

____
____
____
____
____
____

6. From the diagram above, name the structure labeled D, F, I, and L and give the functions of each. **(6 points)**

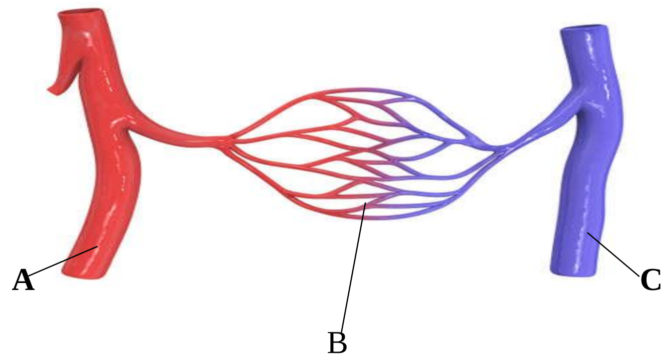
____
____
____
____
____
____
____

7. When structures **E** and **J** become weak what happens to the flow of blood? **(3 points)**

8. Name **the 9 structures** labeled with the following letters from the diagram in **Section A** (5 points): A, F, B, G, C, H, D, O, E

Section B

Instructions: Answer each question in the space provided. The following questions are based on the Mammalian (Human) Circulatory System. Refer to the diagram below to answer all the questions in this section.



9. Name the structures labeled **A, B, and C**? **(2 points)**

____

____

i. Describe the blood transported in structure **A** and structure **C. (3 points)**

____

____

____

ii. Describe the process which occurred in structure **B. (3 points)**

____

____

____

____

____

____

10. Name any three common diseases of the circulatory system and describe how to prevent them. **(5 points)**

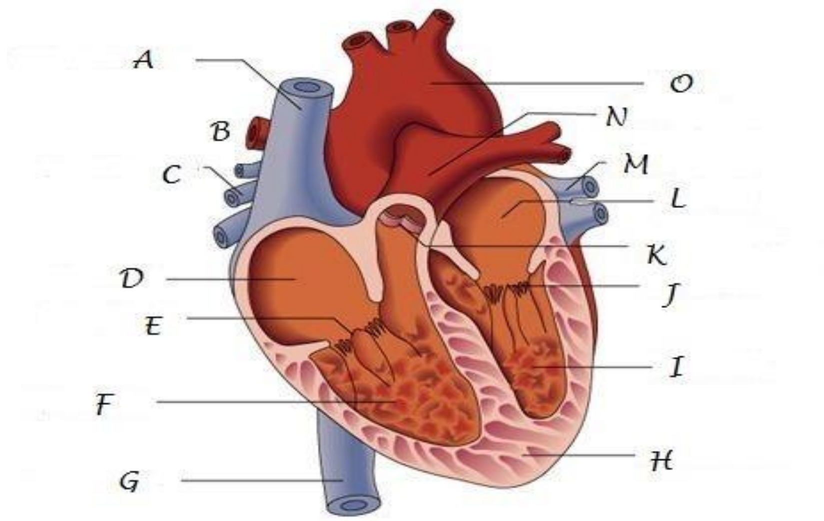
APPENDIX III: POST TEST

BIOLOGY WRITING ASSESSMENT 50 Points

Gender…………… Age: …………………. Form: ………….. Time: 50 Minutes Score:……..

SECTION A

Instructions: Answer each question in the space provided. The following questions are based on the Mammalian (Human) Circulatory System. Refer to the diagram below to answer all the questions in this section.



1. What is the name of the structure labeled **N**? **(1points)**

____

i. Describe the function(s) of the structure labeled **N** in brief. **(3 points)**

____
____
____
____
____

2. What is the name of the structure labeled **M**? **(1 points)**

____

i. Briefly describe the function(s) of the structure labeled **M**. **(3 points)**

3. Outline the flow or pumping of blood in the heart. **(5 points)**

4. Explain the term systole and diastole in the contraction of the heart muscle. **(5 point)**

5. Outline the passage of blood flow from the aorta to the vena cava. **(5 points)**

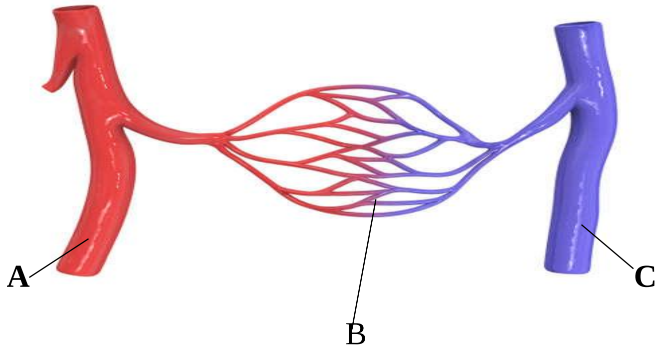
6. From the diagram above, name the structure labeled D, F, I, and L and give the functions of each. **(6 points)**

7. When structures **E** and **J** become weak what happens to the flow of blood? **(3 points)**

8. Name **the 9 structures** labeled with the following letters from the diagram in **Section A** (**5 points**): **A, F, B, G, C, H, D, O, E**

Section B

Instructions: Answer each question in the space provided. The following questions are based on the Mammalian (Human) Circulatory System. Refer to the diagram below to answer all the questions in this section.



9. Name the structures labeled **A, B, and C**? **(2 points)**

____

____

____

i. Describe the blood transported in structure **A** and structure **C. (3 points)**

____

____

____

____

ii. Describe the process which occurred in structure **B. (3 points)**

____

____

____

____

____

____

10. Name any three common diseases of the circulatory system and describe how to prevent them. **(5 points)**

____

____

____

____

____

APPENDIX IV: ANSWERS TO PRE AND POST TEST

1. Pulmonary Arteries (1pts)

i. Functions: transport deoxygenated heart's blood flow to the lungs. Your body's sole arteries that transport blood deficient in oxygen are these ones. (3pts).

2. Pulmonary veins (1pts)

i. Functions: Are blood arteries that transport oxygen-rich blood from the lungs to the left atrial of the heart. (3pts)

3. Right atrium Right ventricle Pulmonary artery Lungs Pulmonary veins
   flow 1 **flow 2** **flow 3** **flow 4** **flow 5**
   Left atrium Left ventricle Aorta to all organs back to the right atrium
   Flow 6 **flow 7** **flow 8** **flow 9** **flow 10** (5pts)
4. During systole, the heart's musculature contracts, delivering blood into the arteries and aorta. Someone's pulse rises during systole. While the heart muscle ceases to contract, it is called diastole. Blood fills the heart chambers, lowering blood pressure in the process. One's blood pressure is determined by the diastole and systole balance. (5pts)
5. Aorta arteries arterioles capillaries venules veins vena cavas
   flow 1 **flow 2** **flow 3** **flow 4** **flow5** **flow6** **flow7 (5pts)**
6. Structure D: Right ventricle; Functions: takes in blood that has entered the heart without oxygen and pumps it into the right ventricle. Function: takes deoxygenated blood from the right ventricle and propels it via the pulmonary artery (Syst. F, Right Ventricular). Functions of Structure I: Left Ventricular Pump: takes blood that has been oxygenated from the Left Atrium and pumps it into the Aorta. Structure: Left atrium; Functions: pumps blood that has been oxygenated from the pulmonary veins into the left atrium. (6pts)
7. Structures E and J are valves of the heart. When they become weak or faulty it causes blood to leak backward in the heart. This condition strain the heart and make the heart work harder and increasing the risk of heart attack. (3pts)
8. Structure **A**: Superior vena cava Structure **F:** Ventricle Structure **B:** Pulmonary artery
   Structure **G:** Inferior vena cava **Structure C:** Pulmonary veins
   Structure **H:** Septum **Structure D:** Right atrium **Structure O:** Aorta
   Structure **E:** Tricuspid valve (5pts)
9. Structure **A** is capillary **Structure B** is capillary bed **Structure C** is vein (2pts)
   i. The blood transported in Structure A is described as oxygenated and Blood transported in Structure C is deoxygenated. (3pts)
   ii. The process which occurred in structure B is diffusion. Exchange oxygen, nutrients, carbon dioxide, waste, etc. occurred in this structure between the cells and the blood.
10. **Arteriosclerosis-** a condition in which the wall of the arteries become clogged/thicken as a result of fatty material deposit such as cholesterol.
    Thrombosis- is the formation of blood clot within the cardiovascular system.
    Varicose veins – are veins that are dilated, elongated, tortuous and palpable as a result of venous hypertension.

APPENDIX V: PARTICIPANTS INFORMATION AND CONSENT LETTER

Kenyatta University Main Campus

Department of COMMTECH

School of Education

Nairobi

Dear Guardian:

Under the Department of Educational Communication and Technology at Kenyatta University, I am a postgraduate student. I would like to request your permission to enable your child/children to part take in an educational research.

The purpose of this investigation is to ascertain how computer-generated 3D animation can improve pupils' comprehension of blood flow within mammalian heart in secondary mixed schools in Thika East. The study’s goal is to provide information that will be useful in assisting biology teachers in improving their approaches to teaching and illustrating biological diagrams, which is a necessary skill for all students to acquire in preparation for KCSE biology paper 3 and pursuing future careers in biological sciences.

Your child will not be permitted to fill out the questionnaire with his or her name.. Participation is completely voluntary. If you have any questions, you can get in touch with the researcher.

If you concur to allow your child part take, please affix your signature.

Sincerely yours,

Hassan Bob Rogers

Email: 21661.2020@students.ku.ac.ke

APPENDIX V I: STATEMENT OF CONSENT

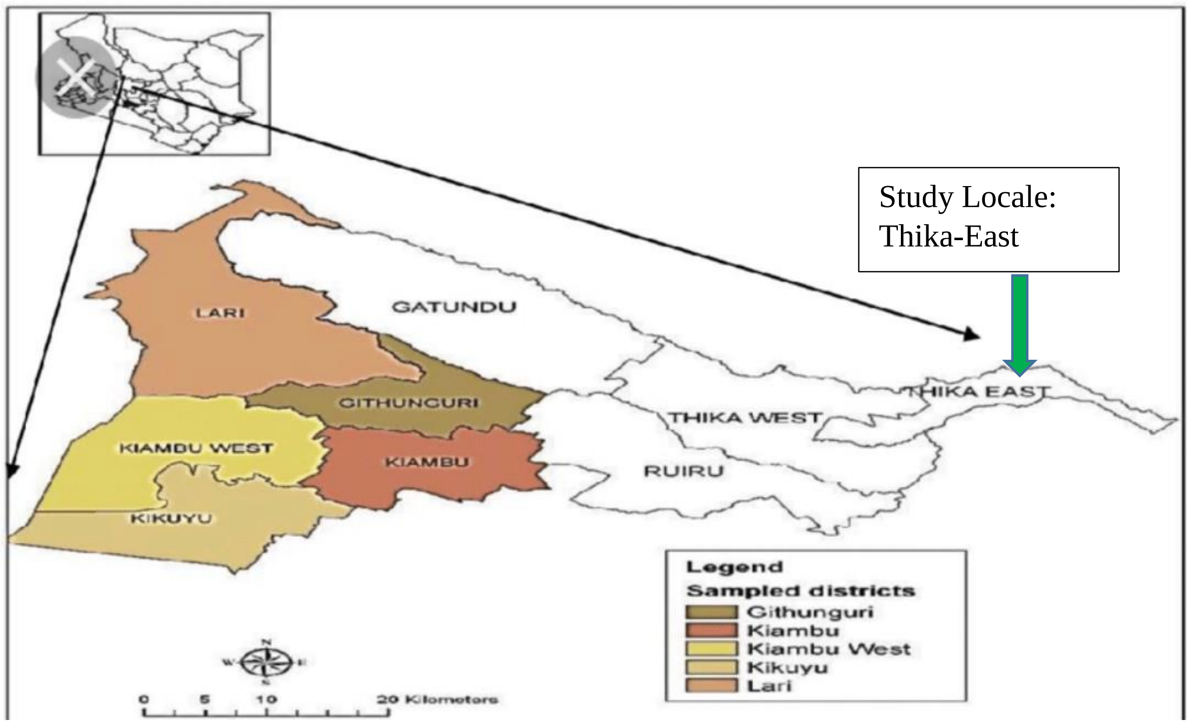
CONSENT STATEMENT

I thoroughly read and comprehend the study's purpose. I accept that participation/cooperation of my child is entirely free ,optional, and my child may opt out of the study at anytime. I have also been informed ,information from my progeny will be used solely for educational purposes and that all personal information will be kept strictly confidential.

I grant authorization on behalf of student……………………………………………….

Parent:…………………………………………………………
Date/Time:……………………………………………………………….

APPENDIX VII: MAP OF STUDY LOCALE- THIKA EAST



APPENDIX VIII : NACOSTI PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR
SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **610492**

Date of Issue: **04/April/2023**

RESEARCH LICENSE

This is to Certify that Mr.. Hassan Bob Rogers of Kenyatta University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kiambu on the topic: Computer 3D Animation Use and Its Effect on Secondary Schools Students\' Conceptual Understanding of Mammalian Circulatory System In Kiambu County, Kenya for the period ending : 04/April/2024.

License No: **NACOSTI/P/23/24569**

610492

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR
SCIENCE,TECHNOLOGY &
INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document,
Scan the QR Code using QR scanner application.

See overleaf for conditions

APPENDIX IX : PRINCIPAL SECRETARY MOE LETTER

Republic of Kenya
MINISTRY OF EDUCATION
State Department for Basic Education

Telegrams: EDUCATION-NAIROBI
Telephone: Nairobi 3318581
FAX. NO: 254-2-214287
Email:ps@education.go.ke
Web: www.education.go.ke
When replying, please quote

JOGOO HOUSE "B"
HARAMBEE AVENUE
P.O. BOX 30040
NAIROBI

Ref. No: MOE.HQS/3/6/85 Vol. II (66)

Date: 11th April, 2023

Hassan Bob Rogers
C/O. Ed. Comm. Tech
Kenyatta University
P.O. Box 43844-00100
NAIROBI

RE: AUTHORITY TO CARRY OUT A RESEARCH STUDY IN KIAMBU COUNTY

Reference is made to your application dated 4th April, 2023 over the above-mentioned subject.

Your request to carry out a research study on "Computer 3D animation use and its effect on Secondary school students' and conceptual understanding of mammalian circulatory system" in Kiambu County, is hereby granted on condition that the exercise will be carried out professionally.

A report on the exercise will be required on completion.

Evelyne Owoko
For: PRINCIPAL SECRETARY

Copy to: County Director of Education: - Kiambu

APPENDIX X: LETTER FROM COUNTY DIRECTOR

MINISTRY OF EDUCATION
State Department of Early Learning and Basic Education

Telephone: Kiambu (office) 0768 970412
Email:directoreducationkiambu@yahoo.com
When replying please quote

COUNTY DIRECTOR OF EDUCATION
KIAMBU COUNTY
P. O. Box 2300
KIAMBU

KBU/CDE/DEPT/ 8/VOL.II

12th April, 2023

Hassan Bob Rogers
Kenyatta University
P.O Box 43844-00100
NAIROBI - KENYA

RE: RESEARCH AUTHORIZATION

Reference is made to NACOSTI letter NACOSTI/P/23/24569 dated 4th April, 2023.

You have been authorized to research on **"Computer 3D animation use and its effect on secondary schools' students conceptual understanding of the mammalian circulatory system in Kiambu County, Kenya"** for a period ending 4th April, 2024.

Please accord him the necessary assistance. You are requested to share with us a copy of your research findings when you conclude your research.

COUNTY DIRECTOR OF EDUCATION
KIAMBU COUNTY
12 APR 2023
P.O. Box 2300 - 00900

SIMON M. WANJOHI
COUNTY DIRECTOR OF EDUCATION
KIAMBU COUNTY

MY EDUCATION, MY FUTURE ***MY EDUCATION, MY FUTURE***

APPENDIX XI : GRADUATE SCHOOL RESEARCH LETTER OF AUTHORIZATION

KENYATTA UNIVERSITY
OFFICE OF THE EXECUTIVE DEAN GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 020-8704150

Our Ref: E55F/21661/2020

DATE: 13th March 2023

Director General,
National Commission for Science, Technology and Innovation
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR MR. HASSAN BOB ROGERS – REG. NO. E55F/21661/2020

I write to introduce Mr. Hassan Bob Rogers who is a Postgraduate Student of this University. He is registered for M.E.d Degree programme in the **Department of Educational Communication and Technology.**

Mr. Rogers intends to conduct research for a M.Ed. thesis Proposal entitled, **"Computer 3D Animation Use and Its Effects on Secondary Schools Students' Conceptual Understanding of Mammalian Circulatory System in Kiambu County, Kenya."**

Any assistance given will be highly appreciated.

Yours faithfully,

PROF. ELISHIBA KIMANI
EXECUTIVE DEAN, GRADUATE SCHOOL

KENYATTA UNIVERSITY
OFFICE OF EXECUTIVE DEAN
13 MAR 2023
GRADUATE SCHOOL
P. O. Box 43844-00100 NAIROBI

Jo/twn